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The individuals and organizations that participate in the New Jersey Climate Adaptation Alliance Advisory Committee agree that the content of this report speaks to compelling issues associated with efforts to enhance preparedness in the public health community with regard to climate change impacts. While individual members of the Alliance Advisory Committee do not necessarily endorse each and every insight outlined in the report, the Alliance Advisory Committee concurs that the content of this report presents critically important issues facing public health practitioners, planners, and decision makers addressing climate-related health outcomes. Rutgers University serves in a defined role as the facilitator of the Alliance. In this role, staff at Rutgers, at the direction of the Advisory Committee, undertook the research that informed development of this report and, as such, recommendations in the report do not represent the position of the University.

Contents

Section I: Executive Summary **1**
Purpose, Partners, Planning and Action 1
A Changing Climate: Temperature, Precipitation, Rising Sea Levels 1
Impacts on New Jersey 2
Next Steps 4
About this Report 6
Section II: Introduction **7**
History of Engagement Efforts 8
Geographic Scope 10
Section III: Climate Trends Affecting New Jersey **13**
Human Activity and Climate Change 13
Temperature 13
Precipitation 17
Sea- Level Rise 18
Section IV: Climate Projections **19**
Understanding Climate Modeling and Emissions Scenarios 19
Projected Changes in Temperature, Precipitation, and Sea Level 20
Section V: Causal Pathways **24**
Air Quality 25
Extreme Heat 35
Extreme Precipitation and Storms 39
Ecosystem Changes and Threats 41
Climate Change Impacts on Mental and Behavioral Health 43
Section VI: Vulnerable Populations **44**
Air Quality 44
Extreme Heat 46
Precipitation Changes and Storms 48
Assessing Social Vulnerability in New Jersey and Flood Risk 49
Ecosystem Changes and Threats 51
Section VII: Next Steps **52**
Act 54
Plan 56
Assess 59
Support 62
Build capacity 64
Bibliography **67**

Section I: Executive Summary

Purpose, Partners, Planning and Action

The United States Global Climate Change Research Program's 2016 report, "*The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment,*" summarizes that climate change is a significant threat to the health of the American people (USGCRP 2016). The U.S. Centers for Disease Control and Prevention (CDC) developed the Building Resilience against Climate Effects (BRACE) framework to support its Climate-Ready States and Cities Initiative to help decision makers prepare for the public health impacts of a changing climate. The New Jersey Climate Adaptation Alliance (NJCAA), which is facilitated by Rutgers University, has developed this **Climate and Health Profile Report** in accordance with the BRACE Step 1 guidelines (CDC 2014) and in consultation with its Climate Change and Public Health Working Group. The report provides a framework to utilize existing data, epidemiological studies, and models of weather patterns to assess the future public health burden from climate risks and to lay the foundation for developing best practices for adaptation.

A Changing Climate: Temperature, Precipitation, Rising Sea Levels

New Jersey's climate is changing. There has been a long-term upward trend of 2.7 °F per century (NCEI 2016). The statewide average temperature for New Jersey in 2012 was the highest in 118 years of records. Nine of the ten warmest calendar years on record have occurred since 1990 and the five warmest years have occurred since 1998, consistent with the long-term upward trend (Broccoli et al. 2013). Unusual summertime warmth has also been a marked impact, with nine of the 15 warmest summers on record occurring since 1999 (Robinson 2016). The summer of 2010 was the warmest on record since statewide record keeping began in 1895; three of four warmest summers on record for New Jersey have occurred since 2010 (Robinson 2016).

There has also been an upward trend in annual precipitation in New Jersey. Since 1895, annual precipitation has increased at a rate of 2.4 inches per century (NCEI 2016a). Increases in the amount of precipitation falling in heavy precipitation events have been noted throughout the northeastern United States; there is reason to expect the trend in heavier precipitation events to continue as the climate warms (Broccoli et al. 2013).

Another observed trend in New Jersey is a rising sea level. Globally, sea levels have risen at an average rate of 1.2 inches per decade since the early 1990s (Alexander et al. 2013). While rates vary globally, the rate of sea level rise is greater along the New Jersey coastal plain, due primarily to land subsidence associated with natural sediment compaction and groundwater withdrawal (Miller et al. 2013). Historically, in Atlantic City, where records extend back to 1912, sea level has risen by an average rate of 1.5 inches per decade over the period of record. (Broccoli et al. 2013). Looking to the future, New Jersey coastal areas are likely (about 67% probability) to experience sea-level rise of 0.6 to 1.0 ft. between 2000 and 2030, and 1.0 to 1.8 ft. between 2000 and 2050. There is about a 1-in-20 chance (5% probability) that sea-level rise will exceed 1.1 ft. by 2030 and 2.0 ft. by 2050 (Kopp, et. al. 2016).

Impacts on New Jersey

Ongoing climate science points to important trends that can affect New Jersey. These changes in climate have the potential to affect population health through both direct and indirect pathways. A direct impact may be an increased rate of heat-related morbidity and mortality as a result of extreme exposures like heatwaves, while indirect impacts of a heatwave might include changes in the pattern of infectious diseases and fluctuation in water flows and food yields. Health consequences resulting from the environmental, ecological, and social impacts of climate change are therefore an equal consideration when planning for climate change and public health (Mcmichael & Lindgren 2011). The most recent research issued by the United States Global Climate Change Research Program (USGCRP 2016), *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, identifies climate drivers that impact health, exposure pathways, health outcomes and factors that influence health outcomes, as well as environmental, social and institutional contexts for conditions to address health outcomes of climate change. The report concludes that climate change is a “significant threat” to the health of Americans and it serves as a critically important assessment and culmination of current science to inform ongoing collaborative efforts in New Jersey. (USGCRP 2016).

Anticipated health impacts from changing climate conditions in New Jersey are summarized in Table 1 below.

Table 1. Overview of Projected Climate Change and Health Impacts in New Jersey

Hazard	Climate Impact	Health Impacts
Air Quality Changes	• Increased ground-level ozone • Fine particulate matter changes • Pollen and allergen production	• Respiratory illness • Cardiovascular disease • Mortality
Extreme Heat	• Increased frequency and intensity of heat waves	• Heat-related illness and mortality • Exacerbation of existing medical conditions • Greater stress on electricity systems potentially leading to health outcomes associated with power outages
Precipitation Changes and Storms	• Flooding • Storms • Drought • Wildfire	• Injuries and fatalities • CO2 poisoning • Food and water contamination • Stress and mental health impacts • Respiratory illnesses • Mold exposure • Food insecurity
Ecosystem Changes and Threats	• Changes in Disease Vector Reproduction and migration patterns	• Vector borne illnesses • Food and water borne illnesses • Harmful Algae Blooms (HABs)

While climate change is likely to affect everyone, not all subgroups will be equally affected. New Jersey is one of the top three most diverse states in the country with respect to race and ethnicity and foreign-born populations, which poses important challenges to delivery of public health systems (NJDOH 2015). Additionally, some populations will be more affected than others, especially the elderly, very young, individuals with existing medical conditions, poorer residents, urban residents, residents of coastal communities, people of color, outdoor laborers and workers in the agricultural, fishing, and tourism industries. In a diverse population like that of New Jersey, it is important to understand the way risk and vulnerability vary across groups in order to target prevention and intervention strategies appropriately.

Next Steps

The Climate and Health Profile report is intended to provide an initial point of reference to inform a targeted set of "next steps" to incorporate conditions of a changing climate into public health planning, programs and policies in New Jersey. Along with insights gained from the New Jersey Climate Change and Public Health Workgroup's June 3, 2016 workshop, *Preparing for the Impacts of a Changing Climate on Public Health in New Jersey: A Workshop for Public Health Practitioners,* the workgroup has outlined a set of next steps forward for its own efforts. In general, the Workgroup concludes that the most effective and efficient approach to protect the public health of New Jerseyans from changing climate conditions is to build consideration of changing climate conditions and the anticipated impact and consequences of those conditions into existing public health programs and systems, rather than creating a new overlay of initiatives on top of existing public health programs and services. Additional work is needed, however, to ensure whether a reliance on existing public health systems and programs is sufficiently protective of the populations and communities that are most vulnerable to changing climate conditions.

The Workgroup has identified a five-part framework to strategically focus its efforts moving forward and it recognizes that advancing these efforts is dependent on a collaborative approach among public health practitioners, state and local decision makers, the research community, healthcare providers, and the nongovernmental community. Overall, success in advancing this framework will be measured by the extent to which changing climate conditions, and the resulting impacts from those conditions, are fully integrated into planning, decision making and delivery of public health programs, policies and services statewide:

Act	•Implement specific actions that have already been identified as important to minimize public health risks from changing climate conditions. •Identify specific communities and populations most vulnerable to changing climate conditions and work in consultation with those populations and communities to design interventions that prioritize their needs.
Plan	•Integrate climate science and projections for changing climate conditions into existing public health programs and decision-making including the State Health Improvement Plan and community health planning conducted by counties and health care systems. •Consider the public health impacts of climate change as part of state and local planning and decision-making such as infrastructure investment, land use planning and community development.
Assess	•Through data analysis and community engagement, assess disease burden resulting from changing climate conditions and make the resulting data available to state and local public health practitioners and health systems to inform planning and programs. •Identify existing public health programs that can be modified to serve as delivery mechanisms for interventions to address health outcomes of changing climate conditions.
Support	•Develop and assist in the deployment of data, tools and other resources to assist local public health practitioners in implementing interventions to address climate-related health outcomes. •Provide support to health systems to anticipate how changing climate conditions may affect their own operations and needs of their patients.
Build Capacity	•Expand the ability of New Jersey's public health practitioners to undertake interventions to address climate-related public health impacts through training, development of best practices, and information sharing. •Educate lawmakers and other decision-makers about the impacts of changing climate conditions on public health in New Jersey and about the resources needed by public health practitioners to address those impacts.

Central among these efforts is fostering collaboration among climate scientists and public health practitioners. In its service role as the state university, a multidisciplinary team at Rutgers has been working to develop and deploy climate science-based decision support tools to aid coastal communities in developing resilience planning efforts. A similar collaborative approach including climate scientists, community leaders and social service providers, public health practitioners, planners and public health experts can provide similar opportunities to take the insights gained from this Climate and Health Profile Report and identify specific and tangible provisions for incorporation into existing planning mechanisms. This effort will be most impactful if done in close collaboration with those agencies and authorities that oversee execution of planning provisions.

Overall, there are significant opportunities to improve health and well-being among New Jerseyans through consideration of climate-related health outcomes. This Climate and Health Profile Report provides an important step forward for development of collaborative initiatives engaging climate scientists, public health practitioners, public policy decision makers, and subject area experts. The Climate Change and Public Health Workgroup provides a helpful forum for advancing work in this important area.

About this Report

A draft version of this report was issued in February 2017. The New Jersey Climate Adaptation Alliance received public comments on the draft report and made revisions to address the comments received in this revised final version. This report begins with a review of NJCAA's history of engagement on climate change and health issues and gives a background on New Jersey's geographic features including climate regions. The next section is a baseline assessment of New Jersey's climate and an analysis of recent trends related to temperature, precipitation and sea-level rise. This is followed by an overview of various climate projections for temperature, precipitation and sea-level rise in New Jersey based on different emissions scenarios. Next, the direct and indirect health impacts of climate change for New Jersey's populations are reviewed, organized by these major categories of climate-related public health hazards: air quality, extreme heat, precipitation changes and storms, ecosystem changes and threats, and mental and behavioral health impacts. The particular groups within New Jersey's population that will be vulnerable to these climate hazards are also reviewed. Finally, the report ends with a preliminary discussion of next steps for planning and action in New Jersey as developed by the NJCAA Climate and Public Health Working Group in accordance with the BRACE framework. Collectively, this report is intended to guide New Jersey's decision makers and stakeholders in understanding the implications of climate change on health and provide the information necessary to develop strategies to address these impacts.

Section II: Introduction

The United States Global Climate Change Research Program's 2016 report, "*The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment,*" gives a blunt appraisal of impacts of climate change on public health:

> *Climate change is a significant threat to the health of the American people. The impacts of human-induced climate change are increasing nationwide. Rising greenhouse gas concentrations result in increases in temperature, changes in precipitation, increases in the frequency and intensity of some extreme weather events, and rising sea levels. These climate change impacts endanger our health by affecting our food and water sources, the air we breathe, the weather we experience, and our interactions with the built and natural environments. As the climate continues to change, the risks to human health continue to grow.*
> (USGCRP 2016)

Figure 1: Building Resilience Against Climate Effects (BRACE) Framework. CDC, 2012.

Source: Centers for Disease Control and Prevention (CDC) http://www.cdc.gov/climateandhealth/brace.htm

New Jersey is not currently a participant in the Centers for Disease Control and Prevention's (CDC) Climate Ready States and Cities Initiative. On behalf of the New Jersey Climate Adaptation Alliance, the Rutgers Climate Institute and Bloustein School have undertaken initial steps under the climate and health adaptation planning process known as BRACE (Building Resilience Against Climate Effects) to position New Jersey for future climate and public health planning activities. Of particular concern are the potential health impacts associated with future climate conditions, including warmer temperatures, increases in precipitation, rising sea levels, and extreme weather events. The first step in this process is the development of a Climate and Health Profile Report to assess baseline climate conditions for the state, and observe climate projections to help identify the scope of health outcomes and vulnerable populations (see Figure 1).

The New Jersey Climate Adaptation Alliance (NJCAA), is a network of public, private and nonprofit organizations that have come together to enhance New Jersey's preparedness for the conditions of a changing climate. The NJCAA, which is facilitated by Rutgers University, has developed this **Climate and Health Profile Report** in accordance with the BRACE guidelines and with input from several current BRACE grantees around the country. This report accomplishes several important objectives, namely it: (1) provides a framework to assess current and future climate and health conditions in New Jersey utilizing existing data, epidemiological studies, and climate projection models to help inform efforts to increase New Jersey's adaptive capacity through planning, policy and program development, (2) seeks to identify gaps in existing datasets that could affect future efforts to develop quantitative measures of health burden in New Jersey, and (3) serves as a foundation for future, more detailed assessments that analyze social vulnerability and project the disease burden associated with changing climate conditions.

While the primary audience of this report is state and local planning and public health staff and policy-makers, the information contained herein may also be a powerful tool for a variety of individuals and organizations in New Jersey working to address climate change as well as organizations that are working to improve the health and well-being of New Jerseyans. The New Jersey Climate and Health Profile Report is intended to be a broad statewide assessment and not a quantitative predictive model of anticipated disease burden as a result of a changing climate.

History of Engagement Efforts

Starting in 2015, the New Jersey Climate Adaptation Alliance (NJCAA) began a concerted effort to implement BRACE in New Jersey. The NJCAA was formed in response to a diverse group of stakeholders who came together on November 29, 2011 at Rutgers University to participate in the conference "Preparing NJ for Climate Change: A Workshop for Decision Makers." The 2011 meeting highlighted the devastating impacts that a changing climate and rising sea levels will have on New Jersey's economy, the health of its residents, the State's natural resources, and the extensive infrastructure system that delivers transportation and communication services, health care, energy and clean water to millions of New Jerseyans. The gathering pointed to the need to undertake proactive climate change preparedness strategies in order to forestall serious public health, economic, ecological and infrastructure investment impacts. Additionally, the workshop pointed to the need to focus New Jersey's preparedness efforts on key areas affecting the State's economy and quality of life: public health; watersheds, rivers and coastal communities; built infrastructure; agriculture; and natural resources. Recommendations clearly pointed to a strong role for Rutgers, as the State University, to work through a stakeholder process to build capacity in New Jersey. Just one year later, In October 2012, New Jersey experienced the devastating effects of Hurricane Sandy. The severe and deadly destruction experienced across the state reinforced the already evident need for action.

Subsequently, analyses undertaken on behalf of the NJCAA were conducted, including two with regard to vulnerable populations. The first identifies areas around the State where there are concentrations of socially vulnerable groups and their nexus to floodplains, and the second examines coastal flood risk to New Jersey's senior citizens (Bickers, 2014; Pflicke et al. 2015; Yamanaka et al. 2015). Bickers (2014) and (Pflicke et al. 2015) borrow the methodology from the Social Vulnerability Index (SOVI) used by the Hazards and Vulnerability Research Institute at the University of South Carolina along with United States Census data. In March 2014, NJCAA released two reports: a "working brief" that summarizes potential impacts to health in New Jersey from the conditions of a changing climate based on a review of public health and scientific data as well as efforts in other states, and a summary of perspectives from members of New Jersey's public health community on challenges and opportunities facing public health professionals in the State with regard to preparing for and responding to the impacts of a changing climate (NJCAA 2014; NJCAA 2014a). The stakeholder engagement report includes input from a post-Sandy focus group of local public health officers, an online survey, and one-on-one interviews targeted at stakeholders and experts. Further, NJCAA also released a "best practice" guide for public health officers in concert with the New Jersey Chapter of the Association of County and City Health Officials (NJCAA, 2014b).

Rutgers staff, through their work on behalf of the NJCAA, were welcomed by CDC to join the national "community of practice" to build adaptive capacity for the public health effects of climate change in New Jersey beginning with their participation in a national meeting of BRACE grantees at CDC in Atlanta to learn about what states and cities are currently doing to address climate change and public health. This opportunity allowed Rutgers staff to connect with and glean guidance from a variety of public health officials around the country. In addition to work being done by Rutgers on behalf of the NJCAA, public health officials and academics in New Jersey have conducted a variety of epidemiological studies to assess the health implications of climate impacts. In particular, a variety of studies were conducted post-Sandy to evaluate the myriad of health impacts of extreme storms.

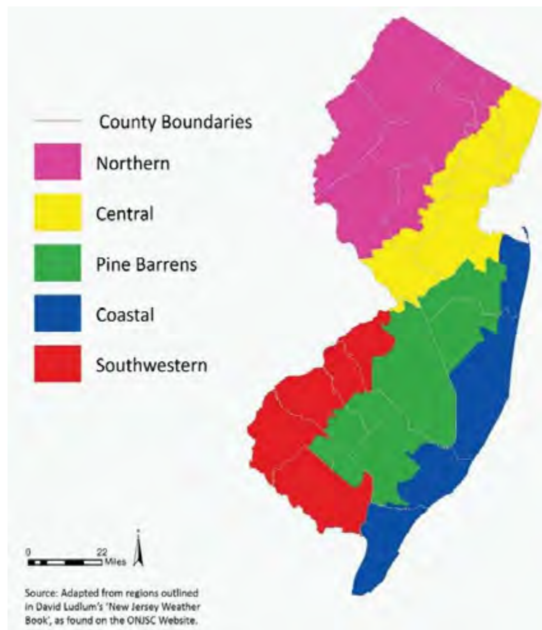
In the fall of 2015, to further and coordinate these efforts, NJCAA formed a Climate Change and Public Health Working Group to work in partnership with New Jersey's public health community to help enhance the public health community's climate preparedness. The working group will follow the BRACE framework to address climate change effects on public health in New Jersey.

Geographic Scope

Despite being a small state in land area, New Jersey has several distinct climate regions and each exhibits unique variations in temperature and precipitation due to differences in land use, terrain, and other geographic components. Understanding the potential variability among climate regions may help in assessing the risk of climate change hazards throughout the state.

New Jersey can be divided into five distinct climate regions: Northern, Central, Pine Barrens, Coastal, and Southwestern (see Figure 2). These regions, exhibited below, were determined with guidance from the Office of the NJ State Climatologist based on the work of David Ludlum (1983). A more in depth description of these five regions are explained in Ludlum's publication, New Jersey Weather Book, and on the Office of the NJ State Climatologist (ONJSC) website. The following descriptions are excerpted from these sources:

Figure 2: New Jersey Climate Regions



The Northern Region

The northern climate region includes the elevated highlands and valleys that are part of the Appalachian Uplands. Climate in this region differs from the rest of the State due to the minimal influence of the Atlantic Ocean on ambient conditions, as well as the orographic effects on clouds and precipitation that occur as air is forced to rise over the highlands. Distance from the ocean contributes to the near double rate of thunderstorms in this region compared to coastal zones, where the ocean helps to stabilize the atmosphere. Temperatures in this northern region are generally cooler than the rest of the State, especially in winter, when average temperature can be as much as ten degrees cooler. The cooler climate results in a shorter growing season in the north compared to other regions.

The Central Region

The central region runs from New York Harbor and the Lower Hudson River to the great bend of the Delaware River near Trenton. This region is characterized by urban corridors that produce large amounts of air pollutants due to the volume of industrial processes and car traffic. The urban environment contributes to warmer temperatures than surrounding suburban and rural areas, as paved surfaces with minimal green space create an “urban heat island effect” (Oke 1982).

The northern edge of the central region is often the boundary between freezing and non-freezing precipitation during winter, and marks the boundary between comfortable and uncomfortable sleeping conditions in summer. Areas to the south of the central region tend to have nearly twice as many days with temperatures above 90°F than in the region as a whole.

The Coastal Region

Climate conditions in the Coastal Region are invariably influenced by proximity to the Atlantic Ocean. In autumn and early winter, when the ocean is warmer than the land surface, the Coastal Region will experience warmer temperatures than interior regions of the state. Likewise, in the spring months, ocean breezes keep temperatures along the coast cooler than the warming land surface. The high heat capacity of the ocean limits the capacity for extreme variations in year round temperature.

Sea breezes play a major role in the coastal climate. When the land is warmed by the sun, heated air rises, allowing cooler air at the ocean surface to spread inland. Sea breezes often penetrate 5-10 miles inland, but under more favorable conditions, can affect locations 25-40 miles inland. They are most common in spring and summer. Coastal storms, often characterized as nor'easters, are most frequent between October and April. These storms track over the coastal plain or up to several hundred miles offshore, bringing strong winds and heavy rains. Rarely does a winter go by without at least one significant coastal storm and some years see upwards of five to ten. Tropical storms and hurricanes are also a special concern along the coast. In some years, they contribute a significant amount to the precipitation totals of the region. Damage during times of high tide can be severe when tropical storms or nor'easters affect the region.

The Pine Barrens Region

The Pine Barrens region is named for the region of scrub pine and oak forests throughout the southwestern portion of New Jersey. Porous, sandy soils have a major effect on the climate of this region. On clear nights, solar radiation absorbed during the day is quickly radiated back into the atmosphere, resulting in surprisingly low minimum temperatures. The porous soil also allows precipitation to rapidly evaporate, creating very dry surfaces. In addition to allowing for a wide range in daily maximum and minimum temperatures, the dry conditions created by porous soil also make this climate zone very vulnerable to wildfires (Ludlum 1983).

The Southwestern Region

The Southwest Region of New Jersey lies between 0-100 feet above sea level. This location and the close proximity to Delaware Bay contribute to a maritime climate in this region. This region experiences the highest average daily temperatures in the State, and without the porous soils that characterize the Pine Barrens, tends to have higher nighttime minimum temperatures. This region receives less precipitation than the Northern and Central regions of the State as there are no orographic features and it is also far enough inland to be away from the heavier rains of some coastal storms. The Southwest therefore receives less precipitation than the neighboring Coastal Region. These precipitation features also allow for a longer growing season. In the fall, frosts usually occur about four weeks later here than in the North and end four weeks earlier in the spring, giving this region the longest growing season in New Jersey.

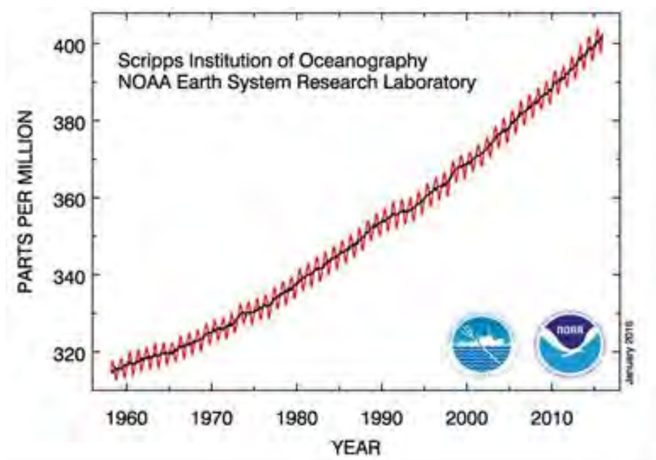
It is worth noting that the climate regions described above do not follow county boundaries. As shown by Figure 2, many counties are divided across regions. Somerset County, for example, is partially in the Central region and partially in the Northern region. Because many of the climate datasets used in this report are aggregated to the county level, we are unable to show them in terms of regions. We make an effort to discuss regional variability where possible but this is simply a limitation of the available data.

Section III: Climate Trends Affecting New Jersey

This Section reviews the association between climate change and human activity, and uses historical data to demonstrate the changes that have been observed in New Jersey's climate. Retrospective climate data for the State of New Jersey are available through the Office of the New Jersey State Climatologist (ONJSC), located at Rutgers University, which serves as the State's primary resource for statewide weather and climate data. New Jersey climate data are also archived at the National Oceanic and Atmospheric Administration's (NOAA) National Center for Environmental Information.

Human Activity and Climate Change

Figure 3: Atmospheric CO2 Concentrations Measured at Mauna Loa Observatory



**Red Line: monthly values; Black Line: 12-month running average. Source: NOAA Earth System Research Laboratory, 2016*

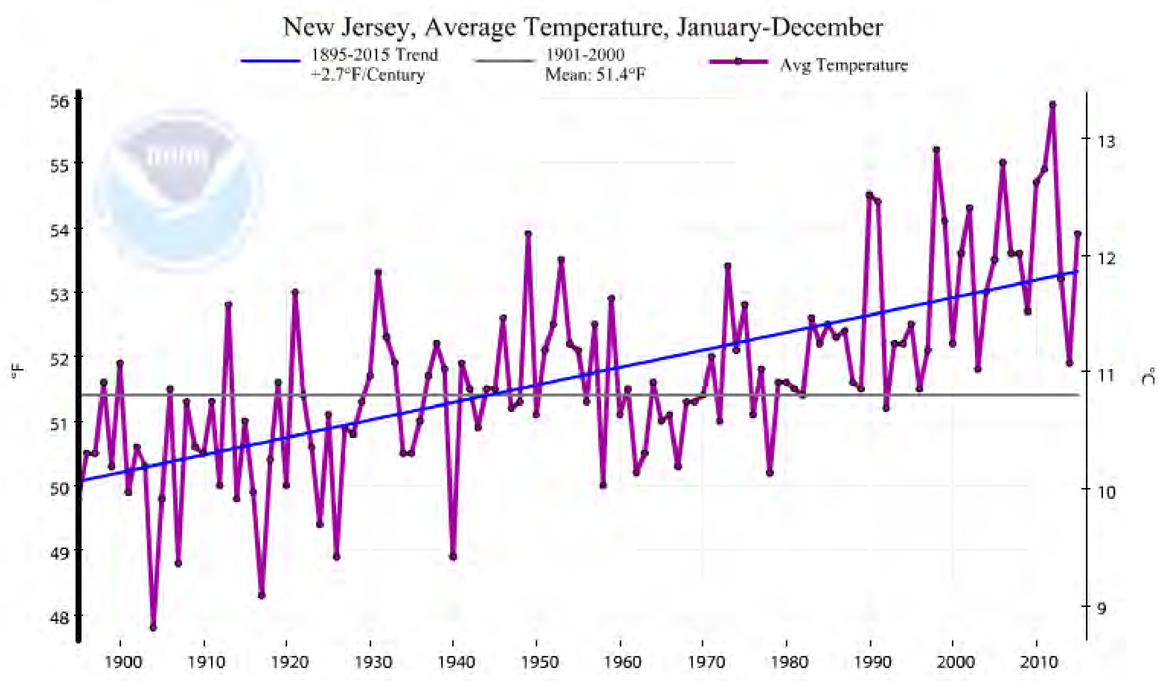
A wide range of indicators show that global climate is changing. The average carbon dioxide concentration in the atmosphere topped 400 parts per million (ppm) in 2013, which far exceeds the range experienced over the last 650,000 years (See Figure 3). The overwhelming majority of scientists agree that the primary cause of climate change in the past 50 years has been human activity (Melillo, Richmond, and Yohe 2014). These changes are influenced by the by-products of human energy production and consumption called greenhouse gases (GHGs) (Marinucci et al. 2014). Greenhouse gases emitted by human activity include CO2, nitrous oxide, methane, and fluorinated gases. (Broccoli et al. 2013). GHGs create a barrier for solar radiation and heat produced by the sun to escape the Earth's surface. Global climate change is projected to continue through the 21st century and beyond, though the specific changes we see will depend primarily on the GHGs emitted and the adaptation practices - a term used to describe preparatory and responsive measures - we put into place (Melillo, Richmond, and Yohe 2014).

Temperature

Like other states across the Northeast, New Jersey experiences pronounced seasonal cycles, each with unique meteorological conditions. However, some seasonal characteristics have been changing in recent decades, most notably through rising temperatures. As a whole, the Northeast has experienced an increase in temperature of about 2°F since 1895, or 0.16°F per decade (Horton et al. 2014).

As shown in Figure 4, there has been a long-term upward trend of 2.7° F per century (NCEI 2016). Nine of the ten warmest calendar years on record have occurred since 1990 and the five warmest years have occurred since 1998, consistent with the long-term upward trend (Broccoli et al. 2013). Unusual summertime warmth has also been a marked impact, with nine of the 15 warmest summers on record occurring since 1999 (Robinson 2016). The summer of 2010 was the warmest on record since statewide record keeping began in 1895; three of four warmest summers on record for New Jersey have occurred since 2010 (Robinson 2016).

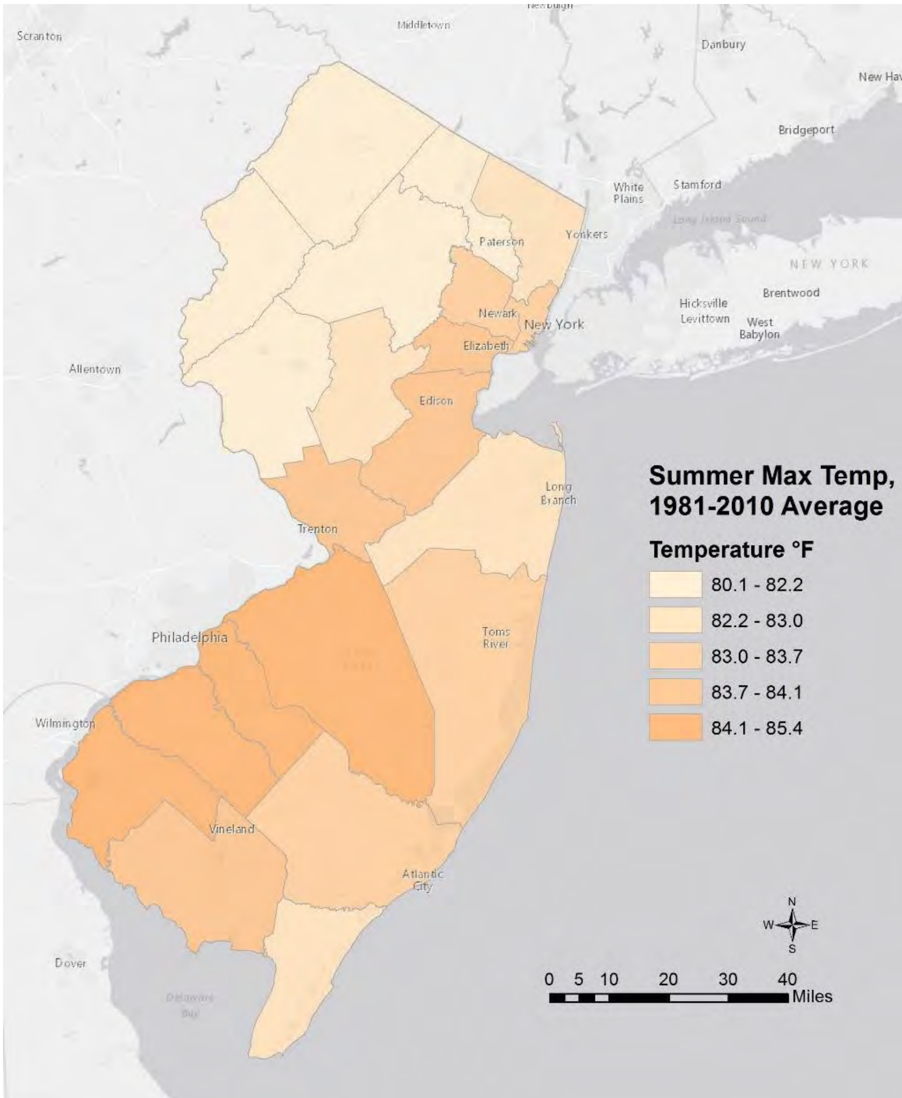
Figure 4: New Jersey Statewide Average Annual Temperature, 1895-2015



Source: NOAA National Center for Environmental Information (2016)

In a northeastern state such as New Jersey, the variation in temperature throughout the State throughout the year is significant in understanding the potential impact of climate change. To give a sense of this seasonal temperature variation, Figures 5 and 6 show the average summer maximum and average winter minimum temperatures based on monthly station averages for 1981-2010. Summer is defined here as the months of June, July and August. Winter is defined as December, January, and February.

Figure 5: New Jersey Summer Maximum Temperature, 1981-2010 in °F

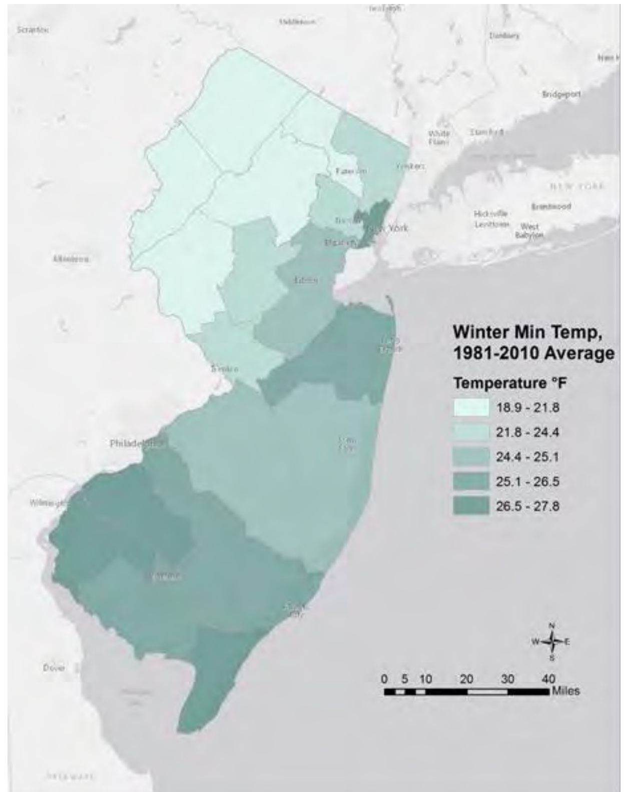


Data source: PRISM Climate Group, Oregon State University 2016

On average, the southern portion of the state experiences slightly warmer summer and winter temperatures while the northern portion is cooler. However, the area around Newark in the northern part of the state experiences slightly warmer temperatures than the rest of that region likely due to its urban character. The average January minimum temperature for the State ranged from 15°F to about 28°F, while the average July maximum temperature was between 84°F and 88°F (PRISM Climate Group 2016).

It is important to note that because we are observing temperature differences based on station averages, it is likely that some microclimates within the state are being masked, in particular, areas where urban heat island effect is causing warmer average temperatures. Heat island is a term used to describe the phenomenon of urban areas experiencing warmer temperatures than surrounding suburban and rural areas. This is due to the amount of built up environment and concrete typically found in urban settings (EPA 2015c). Urban heat island effect may be particularly pronounced around some New Jersey cities including Newark and Camden.

Figure 6: New Jersey Winter Minimum Temperature, 1981-2010 in °F



Data source: PRISM Climate Group, Oregon State University 2016

In addition to increases in annual and seasonal temperatures, the number of hot and extremely hot days has been increasing throughout the Northeast and is expected to continue increasing in the coming decades (Horton et al. 2014).[1]

The Southwestern and Pine Barrens regions of the State tend to experience a warmer average temperature and less annual precipitation than other areas—particularly the Northern region, which is much cooler and wetter on average. Like most northeastern states, New Jersey experiences a wide spectrum of weather conditions—from the low temperatures of spring and winter to the pronounced heat of the summer months.

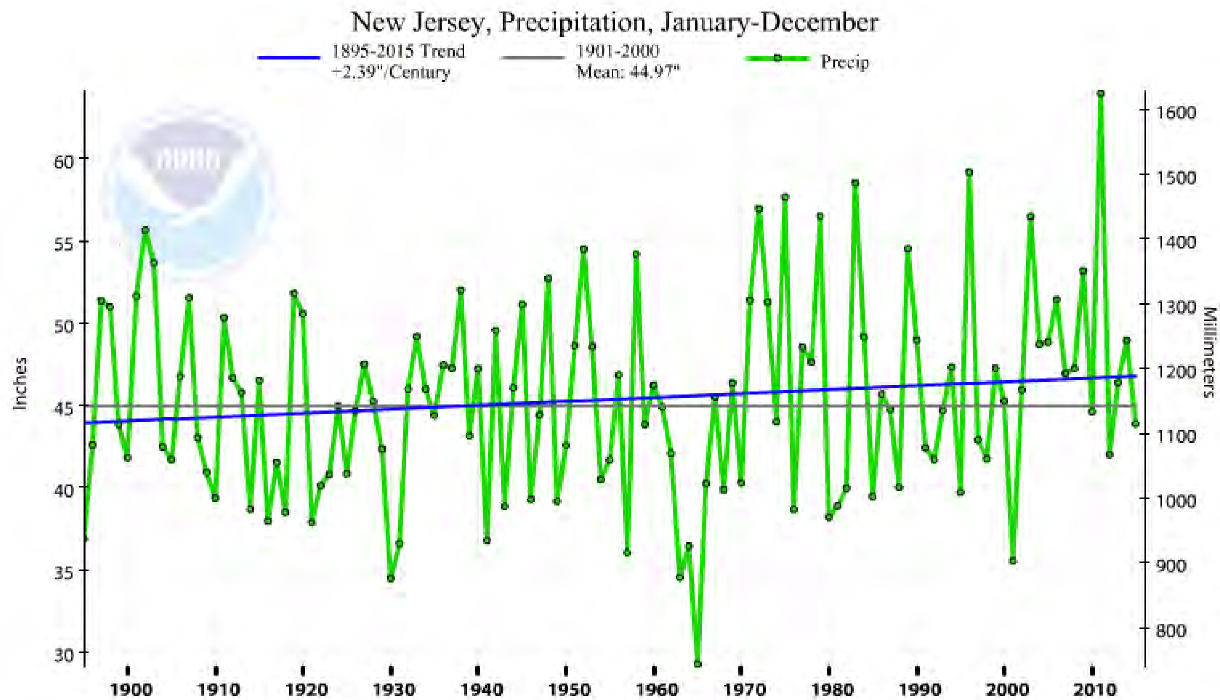
However, the past few decades have been characterized by more unusually warm months than by unusually cold months (Broccoli et al. 2013). With increases in both average temperature and extreme heat days projected over the next several decades, summertime heat will be a particularly dangerous impact for the State's vulnerable populations including the elderly, people of color, people with already compromised health and the urban poor.

[1] Extremely hot days are defined here as days with daily maximum temperatures that exceed 95°F. Hot days are defined as days with daily maximum temperatures that exceed 90°F. The literature is inconsistent in its definition of these terms and some sources define extremely hot days as daily maximum temperatures above 100°F.

Precipitation

There has been an upward trend in annual precipitation in New Jersey (See Figure 7). Since 1895, annual precipitation has increased at a rate of 2.4 inches per century (NCEI 2016a). It is important to note, however, that the decade-to-decade variability in annual precipitation is quite large and can overwhelm any long-term trends. Precipitation was well below average during the drought of the early 1960s, but much wetter conditions prevailed during the 1970s (Broccoli et al. 2013).

Figure 7: New Jersey Statewide Annual Inches of Precipitation, 1895-2016



Source: NOAA National Center for Environmental Information (2016a)

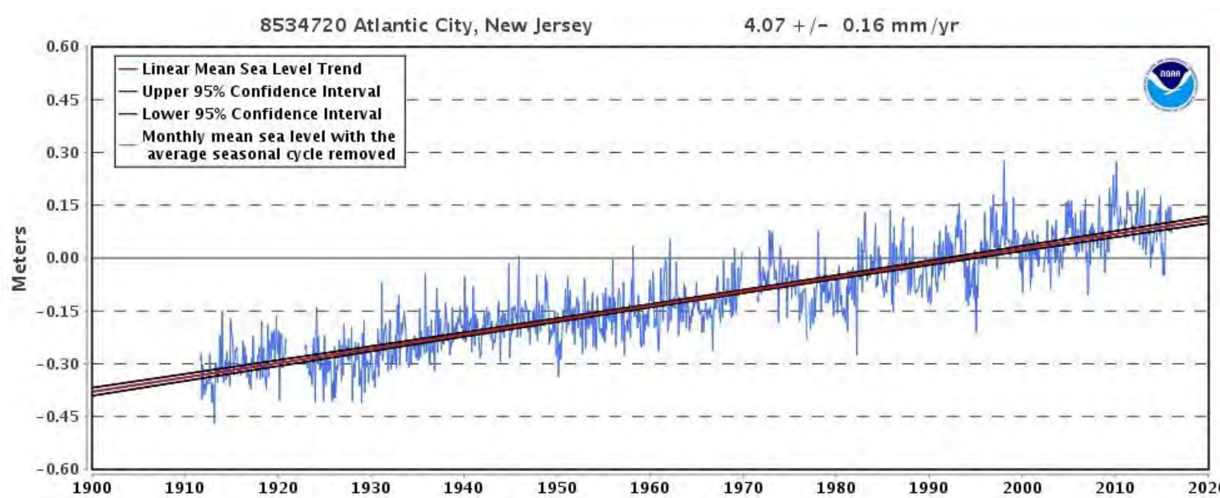
The last decade has also been unusually wet. The heaviest precipitation amount for six of the twelve calendar months (March, April, June, August, October and December) has occurred since 2003, with August 2011 weighing in as the all-time wettest month since statewide records began in 1895. Increases in the amount of precipitation falling in heavy precipitation events have been noted throughout the northeastern United States. In fact, the Northeast has experienced the greatest increase in extreme precipitation of any of the other U.S. regions (Horton et al. 2014). There is reason to expect that this trend may continue, as the Intergovernmental Panel on Climate Change (IPCC) projects that "extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will very likely become more intense and more frequent by the end of this century, as global mean surface temperature increases" (Alexander et al. 2013; Broccoli et al. 2013).

Sea- Level Rise

Another important climate change impact in New Jersey is sea-level rise, given the state's large coastal zone. Coastal areas are particularly susceptible to flood inundation. Global sea level rose at an average rate of 0.6 inches per decade during the 20th century, driven primarily by two processes: the thermal expansion of a warming ocean, which makes the same amount of water take up more space, and melting glaciers and ice sheets, which add water to the ocean (Broccoli et al. 2013). The rate of global sea-level rise has increased in recent decades, with an average rate of 1.2 inches per decade since the early 1990s (Broccoli et al. 2013). This trend is expected to continue into the next century, due in part to the melting of the Greenland and West Antarctic ice sheets that add water to the ocean basins (Joughin et al. 2014).

Rates of sea-level rise vary globally and sea levels along the New Jersey shore have risen faster than the global average due primarily to land subsidence associated with natural sediment compaction and groundwater withdrawal (Miller et al., 2013). Historically, in Atlantic City, where records extend back to 1912 (see Figure 8), sea level has risen by an average rate of 1.5 inches per decade over the period of record (Broccoli et al. 2013).

Figure 8: Mean Sea Level Trend, Atlantic City



The mean sea level trend is 4.07 millimeters/year with a 95% confidence interval of +/- 0.16 mm/yr based on monthly mean sea level fata from 1911 to 2015 which is equivalent to a change of 1.33 feet in 100 years. Data source: National Oceanic and Atmospheric Administration (NOAA) 2016, https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8534720

Section IV: Climate Projections

This section details a range of projected changes to New Jersey's climate based on current climate science and modeling techniques. Climate model projections illustrate how the climate system is expected to behave under specific scenarios of greenhouse gas emissions. The goal of presenting climate projections is to better understand the spectrum of effects and the range of possible impacts of climate change, particularly with regard to health hazards and vulnerabilities.

As with any effort to predict into the future, there is inherent uncertainty in climate projections. This uncertainty is caused, in large part, by the range of possible future scenarios based on various human decisions. If we as a society increase our efforts toward greenhouse gas mitigation and severely reduce our greenhouse gas emissions, the future will look different than if we do little or nothing to curb emissions. Additional factors including population growth, economic activity, energy conservation, and land use will impact the future as well (EPA 2015d). To account for this, climate projection models use a wide range of emissions scenarios. Emissions scenarios help train the models by estimating the amount of greenhouse gases in each time period being projected, among other factors. It is important to take into consideration the range of possible climate impacts that result from these different models and emissions scenarios.

Understanding Climate Modeling and Emissions Scenarios

The Intergovernmental Panel on Climate Change (IPCC), the international body for assessing climate change science, provides assessments of the scientific basis of climate change. In 2000, the IPCC published a set of emissions scenarios intended to guide climate change projections called The Special Report on Emissions Scenarios (SRES). The report included 40 separate emissions scenarios that comprised unique combinations of assumptions for future greenhouse gas pollution and other driving forces. The scenarios were organized into four families: A1, A2, B1, and B2. Additional assessments were published in 2001 and 2007 using the same framework and emissions families (World Meteorological Organization, n.d). The SRES was subsequently replaced by Representative Concentration Pathways (RCPs) in the IPCC fifth assessment. RCPs differ from SRES in that they do not have detailed socioeconomic narratives or scenarios and are instead based on radiative forcing. RCP scenarios are names after the possible range of radiative forcing values in 2100 relative to pre-industrial values—RCP 2.6, RCP 4.5, RCP 6, and RCP 8.5 (Weyant et al. 2009). Figure 9 shows temperature projections for various emissions scenarios.

Figure 9: Comparison of Low (B1 and RCP 2.6) and High (A2 and RCP 8.5) Range Emissions Scenarios for RCP and SRES

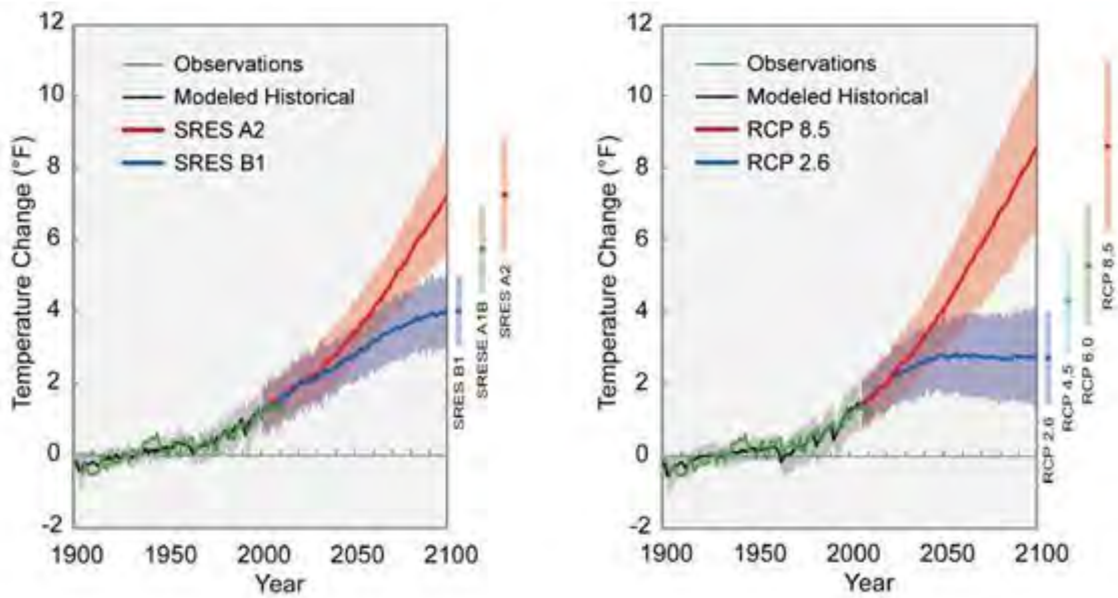
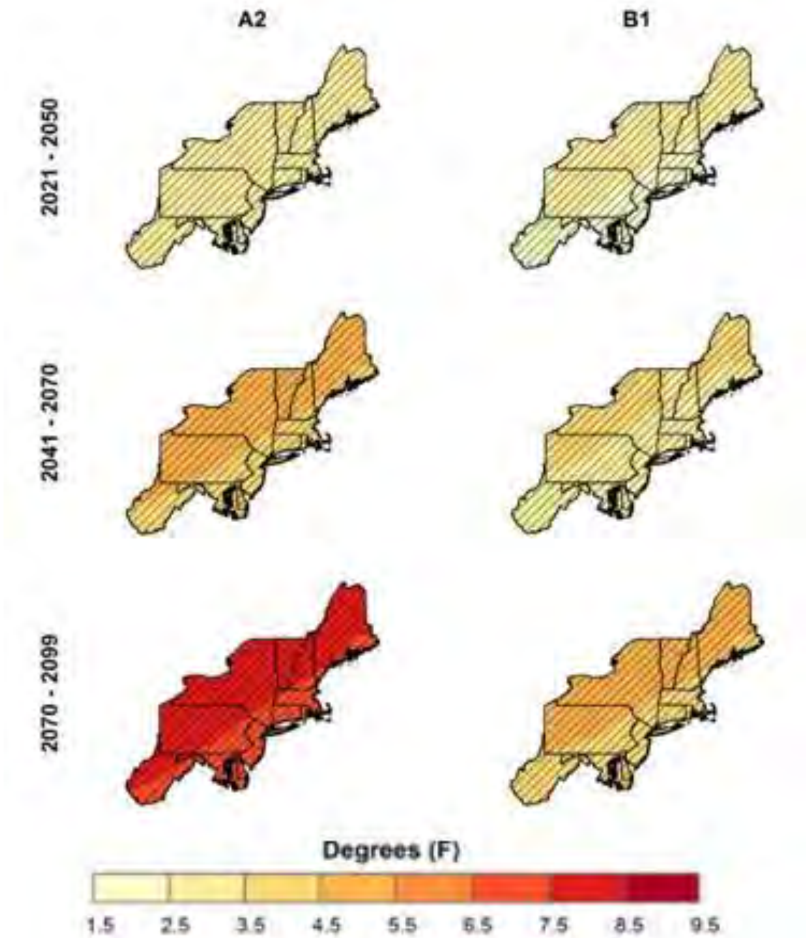


Image source: Emission levels from SRES and RCPs scenarios, Walsh et al. 2014

Projected Changes in Temperature, Precipitation, and Sea Level

Observed climate changes for the Northeast and New Jersey demonstrate that the region is getting warmer and wetter. Future climate projections, both under SRES and RCP scenarios, predict that these trends will continue through the end of the century. One set of projections used in the National Climate Assessment predicts that the Northeast could experience warming ranging from 3 to 10 ºF by the 2080s (see Figure 10) (Kunkel et al. 2013). Temperatures in the region are projected to increase the most in the winter and the least amount of warming is projected for the spring (Kunkel et al. 2013), The number of annual days with maximum temperatures greater than 90 ºF are expected to increase 30-40 days in high elevation areas of northern New Jersey and to 60-70 days in south central areas of the State by the period 2041-2070; this is an increase of about 20 to 30 more days in the northern part of New Jersey and about 40 more days in south central New Jersey above an historic baseline of 1971-2000 (see Figure 11) (Horton et al. 2014). In addition, the frequency, intensity and duration of heat waves is expected to increase.

Figure 10: Multi-Model Mean Annual Temperature Projections in °F, Anomalies Relative to 1971-1999 Average



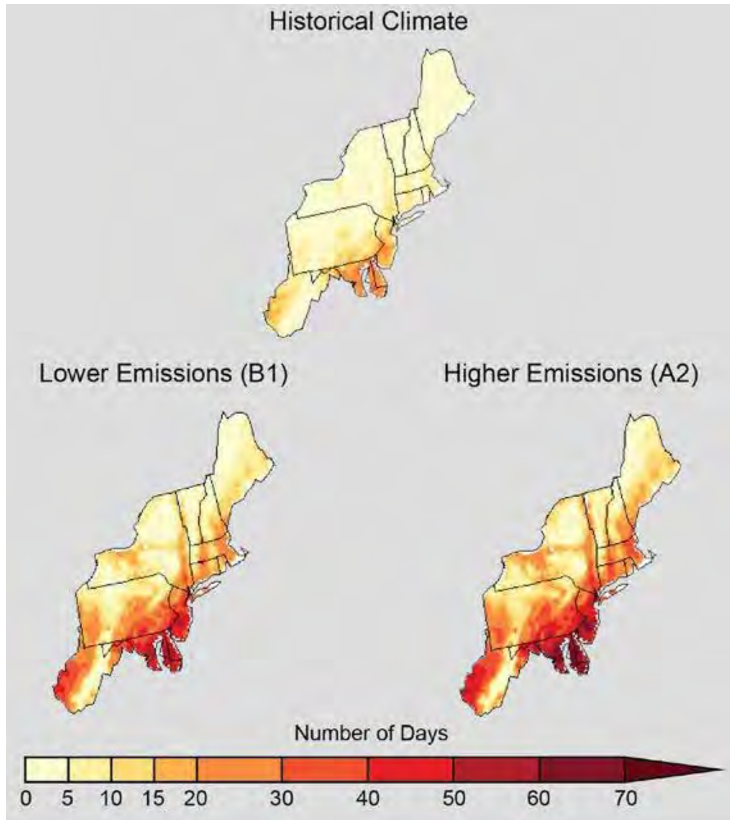
Simulated difference in annual mean temperature (°F) for the Northeast region, for each future time period (2021-2050, 2041-2070, and 2070-2099) with respect to the reference period of 1971-1999. These are multi-model means for the high (A2) and low (B1) emissions scenarios from the 14 (B1) or 15 (A2) CMIP3 global climate simulations. Color with hatching (category 3) indicates that more than 50% of the models show a statistically significant change in temperature, and more than 67% agree on the sign of the change.

Source: Kunkel, et. al, 2013: Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 1. Climate of the Northeast U.S, NOAA Technical Report NESDIS

Projections of precipitation changes are less certain than projections of temperature increases (Kunkel et al. 2013). However, projections for the Northeast predict that under a high emissions scenario, the region could experience an increase in winter precipitation between 5% and 20% by the end of the century. Summer and fall precipitation projections, as well as precipitation for the entire year are generally small at the end of the century compared to natural variations (Horton et al. 2014). Summer time and fall droughts could become more frequent as temperatures rise, resulting in increased evaporation and earlier winter and spring snowmelt (Horton et al. 2014). Projections also show that there is likely to be an increase in the occurrence of heavy precipitation events in the Northeast, which could lead to an increase in annual flood events (Melillo 2014). This trend is currently being observed. Projections made in the 1950s about storms expected to occur once in 100 years are now projected to occur once every 60 years (Horton et al. 2014).

The IPCC has concluded that the global frequency of tropical cyclones is not projected to increase, while maximum wind speeds will likely increase. Precipitation intensity during tropical cyclones is likely to increase. The global frequency of extratropical cyclones is not likely to change substantially. Changes to extratropical storm tracks in the North Atlantic are possible, but have not been reliably established (Stocker et. al., 2013).

Figure 11: Projected Increases in the Number of Days over 90°F



Projected number of days per year with a maximum temperature greater than 90 °F averaged between 2041 and 2070, compared to 1971-2000, assuming continued increases in global emission (A2) and substantial reductions in future emissions (B1). (Figure Source: NOAA NCDC/ CICS-NC).

Changes in temperature and precipitation will also lead to changes in season length. Summer is projected to arrive earlier and extend longer into the fall by mid-century, impacting the length of the growing season (Horton et al. 2014).

The current global trend in sea-level rise is expected to continue into the next century, making coastal communities particularly vulnerable to flood inundation. Looking to the future, New Jersey coastal areas are likely (about 67% probability) to experience sea-level rise of 0.6 to 1.0 ft. between 2000 and 2030, and 1.0 to 1.8 ft. between 2000 and 2050. There is about a 1-in-20 chance (5% probability) that sea-level rise will exceed 1.1 ft. by 2030 and 2.0 ft. by 2050 (See Figure 12). While it is certain that the trend in sea-level rise will continue, projected ranges are relatively wide because we do not know what future emissions will be like or how rapidly ice sheets will respond. Regardless, higher sea levels will increase the baseline for flooding from coastal storms.

Figure 12: Projected SLR Estimates for New Jersey (ft.)

	Middle Estimate	Likely Range	1-in-20 Chance	1-in-200 Chance	1-in-1000 Chance
Year	50% probability SLR meets or exceeds…	67% probability SLR is between…	5% probability SLR meets or exceeds…	0.5% probability SLR meets or exceeds…	0.1% probability SLR meets or exceeds…
2030	0.8ft	0.6 – 1.0ft	1.1ft	1.3ft	1.5ft
2050	1.4ft	1.0 – 1.8ft	2.0ft	2.4ft	2.8ft
2100 Low emissions	2.3ft	1.7 – 3.1ft	3.8ft	5.9ft	8.3ft
2100 High emissions	3.4ft	2.4 – 4.5ft	5.3ft	7.2ft	10.0ft

Source: Kopp, et. al. 2016

Estimates are based on (Kopp et al., 2014). Columns correspond to different projection probabilities. For example, the 'Likely Range' column corresponds to the range between the 17th and 83rd percentile; consistent with the terms used by the Intergovernmental Panel on Climate Change (Mastrandrea et al., 2010). All values are with respect to a 1991-2009 baseline. Note that these results represent a single way of estimating the probability of different levels of SLR; alternative methods may yield higher or lower estimates of the probability of high-end outcomes.

Section V: Causal Pathways

The physical environment is one of the key determinants of health as identified by the World Health Organization (WHO). As such, observed and projected changes to climate pose a serious threat to the health and well-being of New Jersey residents. While some of these impacts will be direct outcomes of climate change, it is important to acknowledge that many of the health effects to be faced are indirect. For example, a direct impact may be an increased rate of heat-related morbidity and mortality as a result of extreme exposures like heatwaves, while indirect impacts of a heatwave might include changes in the pattern of infectious diseases and fluctuation in water flows and food yields (See Figure 13). Health consequences resulting from the environmental, ecological, and social impacts of climate change are therefore an equal consideration when planning for climate change and public health (Mcmichael & Lindgren 2011). This section reviews direct and indirect health and mental health impacts of climate change hazards, including those impacts caused by: changes in air quality, extreme heat, extreme precipitation and storms, and ecosystem changes and threats. All of the associations discussed in this section take the geographic and population features of New Jersey in account in order to assess the potential impacts of climate change throughout the state.

Figure 13: Conceptual Pathways of Climate and Health

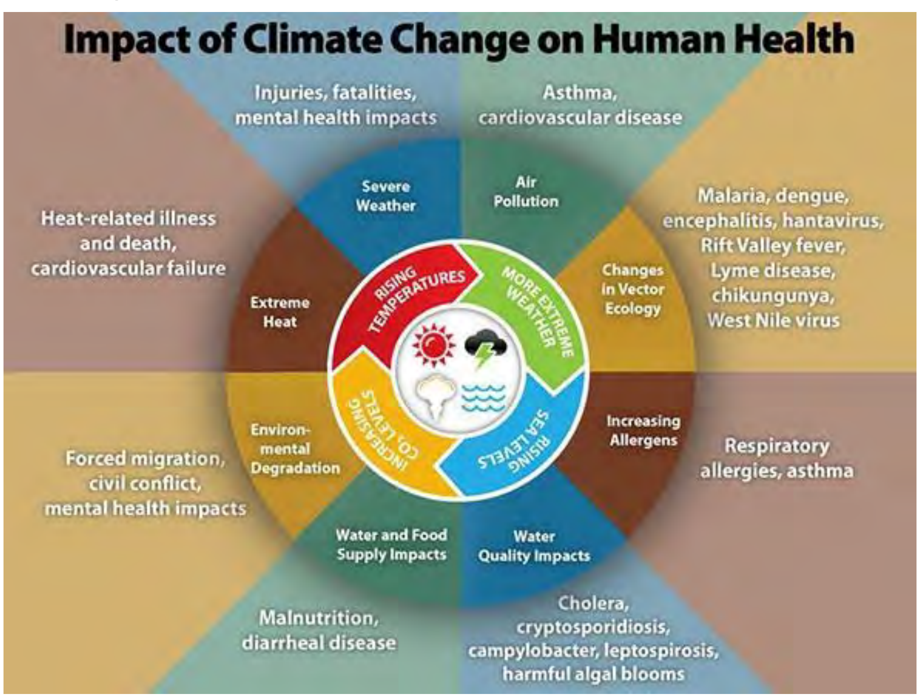


Image Source: CDC Climate Effects on Health – www.cdc.gov/climateandhealth/effects/

Air Quality

Changing climate conditions that affect air quality include:

- Increasing atmospheric carbon dioxide
- Increasing temperatures
- Changes in precipitation patterns
- Extreme weather events
- Changes in cloudiness, humidity and wind speed (USGCRP 2016).

The United States Global Climate Change Research Program (USGCRP 2016) points to three key findings where, with high confidence, changing climate conditions are expected to affect air quality resulting in health impacts:

- Increases in formation of ground level ozone as a result of meteorological conditions that are more conducive to ozone-formation, leading to premature deaths, hospital visits, lost school and work days, and increases in incidence of acute respiratory conditions;
- Increases in the number and severity of naturally occurring wildfires leading to increased emissions of particulate matter and ozone precursors causing additional chronic and acute cardiovascular and respiratory health outcomes; and
- Increases in temperature, changes in precipitation patterns and increased atmospheric carbon dioxide concentrations leading to increases in airborne allergies, asthma and other allergy-related illnesses.

Air quality exposures are grouped here as outdoor air quality, indoor air quality, and aeroallergens:

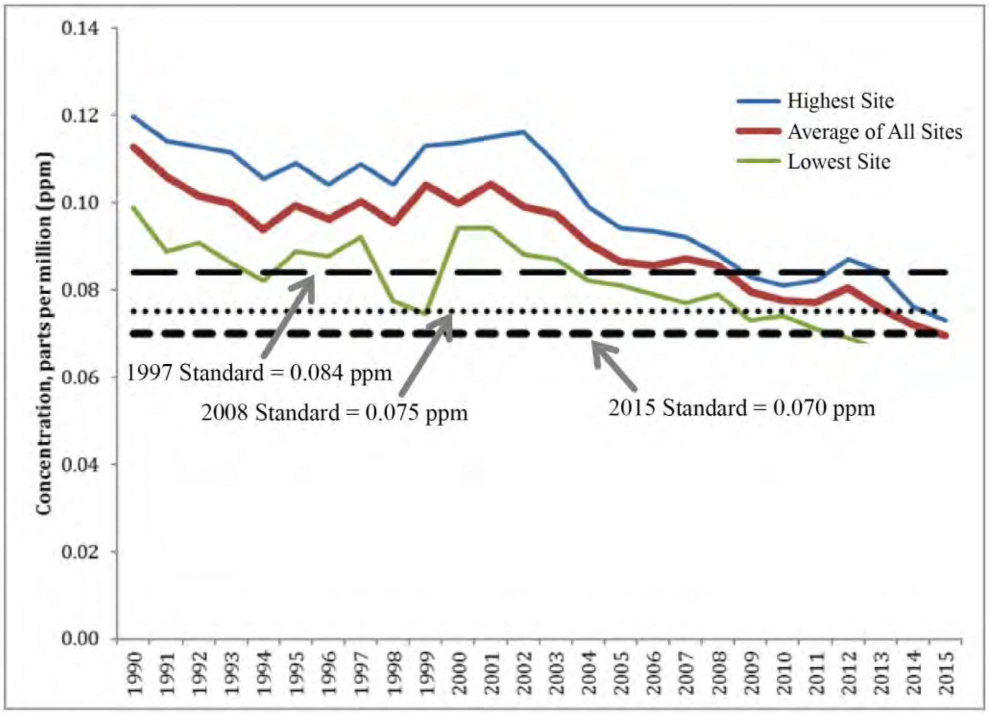
Outdoor air quality

Changing climate conditions influence the level and concentration of pollutants such as ground-level ozone (O3), and particulate matter. Ground level ozone, a major component of smog, is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOCs) in the presence of sunlight. NOx and VOC emissions, referred to as ozone precursors, come from industrial operations, electric utilities, motor vehicles and chemical solvents (USEPA 2016a). In addition to ozone precursors emitted by sources within the state, transported pollution brought into the region by the wind also adds to ground-level ozone concentrations in New Jersey (NJDEP 2016a). Ground level ozone formation is affected by weather and climate and warming temperatures are expected to increase the concentration of ground level ozone in outdoor air. Higher temperatures can increase the chemical rates at which ozone is formed via precursor emissions from manmade and biogenic sources. Stagnation events, in which a local air mass does not change over a period of several days and allows ozone to accumulate, are increasing in frequency and expected to continue to increase (Fann et al. 2016). Even though other climate factors are expected to reduce ozone formation such as increased water vapor concentrations in some locations, experts find climate-driven changes in ozone favor a likely increase of ozone concentrations in the United States and these changes are more consistently reported for the northeastern United States (Fann et al. 2016). Studies have shown that ozone is highly correlated with meteorological variables and as much of 80% of the variance in maximum daily ozone in the eastern U.S. can be explained by a model including temperature (with a positive correlation) and relative humidity (with a negative correlation). (Jacob et al. 2009). In 2009, the US Global Change Research Program completed an interim report to assess how climate change would affect air quality. This report synthesized the findings of a number of EPA-funded modeling studies and the consensus among most research groups was that year 2050 simulated climate change would increase ground-level O3 concentrations, in the range of 2-8 ppb, in every region of the country (USEPA 2009). Although the purpose of the report was to synthesize the impact of future climate change on air quality, independent of changes in anthropogenic emissions, a variety of models and modeling configurations lead to variability in the results. Research communities providing results for this report used general circulation models (GCM), global chemistry and transport models (GCTM), regional climate models (RCM), and regional air quality models (RAQM). However, across a variety of model simulations, there was evidence for an increase in O3 in the Northeastern US. Individual studies that have focused on the northeastern U.S. and/or New York City have similarly projected increases in O3 concentration for the 2050 timeframe (Liao et al. 2010 and Hogrefe et al. 2004). Thus, a warming climate is likely to bring increased ground-level ozone concentrations, particularly in the eastern U.S.

Ground level ozone is a strong lung irritant that has been associated with increased hospitalizations for pneumonia, chronic obstructive pulmonary disease (COPD), asthma and allergy (Ebi et al. 2008). It is likely that ozone has cardiovascular health effects and there has also been a suggestion that exposure to ozone is associated with adverse impacts on the reproductive systems of both males and females, and effects on brain health (USEPA 2013). Exposure to ozone is also associated with shorter life expectancy. The elderly, children, and those with pre-existing medical conditions, have been found to be particularly susceptible (Bell et al 2014).

The Clean Air Act requires that the US EPA set National Ambient Air Quality Standards (NAAQS) for six criteria pollutants, including ground-level ozone. Once a NAAQS is established or revised, the US EPA goes through a process to designate all areas of the country as either in attainment or nonattainment for each standard depending on whether or not the area meets the standard. In 2012 the entire state of New Jersey was designated as nonattainment for the ozone standard (USEPA 2016a). New Jersey adopted its plan to achieve attainment with the national standard in June 2015 (http://www.state.nj.us/dep/baqp/ozoneco2011inv.html). Efforts to reduce ground level ozone concentrations in New Jersey include establishment of standards aimed at reducing VOCs in products such as paints and on requiring gasoline vapor recovery systems at gas stations. Other efforts have included regulatory standards on motor vehicles and off-road equipment, solvent decreasing, asphalt paving, fuel loading at marine terminals, and controls on refineries. Additional efforts have focused on ensuring reductions in NOx through standards set to promote low emissions vehicles, power plant and refinery mandatory requirements and motor vehicle standards. Ongoing efforts to address emissions resulting from high electric demand days, power plants and vehicles as well as standards to address mercury and air toxics pollutants from electric power generating units are expected to further reduce NOx emissions (NJDEP 2016a). Due to pollution reduction efforts within the state, as well as reductions in transported pollution entering the states, New Jersey has been experiencing an overall improvement in ozone levels as indicated below in Figure 14 which shows the statewide annual ozone average from 1990-2015.

Figure 14: Ozone Trends in New Jersey, 1990-2015



Source: New Jersey Department of Environmental Protection (NJDEP 2017)

In 2015, the EPA promulgated a final rule lowering the 8-hour ozone standard to 70 ppb. Despite the overall statewide decline in ozone, the number of days that exceeded the new 70 ppb standard was 32 in 2015 and 25 in 2016 (NJDEP 2017). The EPA Clean Air Science Advisory Council (CASAC) had recommended a health-based standard of 60 or 65 ppb, arguing that scientific evidence points to little margin of safety for the protection of public health, particularly for sensitive subpopulations at a standard of 70 ppb. The Committee indicated that "although a level of 70 ppb is more protective of public health than the current standard, it may not meet the statutory requirement to protect public health with an adequate margin of safety (USEPA CASAC 2014)." Figure 14 reflects trends on an annual basis, however, ozone is exacerbated in warmer temperatures such as the summer season.

Particulate matter air pollution (PM) is a mixture of solid and/or liquid particles that are either directly emitted from sources as "primary pollutants," or are formed in the atmosphere from reactions of gas-phase precursors as "secondary air pollutants," often along with ozone as components of smog. Direct sources of PM include factories, power plants, cars and trucks, wood-burning stoves and forest fires. Sources of precursor compounds for secondary formation of PM include sulfur dioxides, nitrogen oxides, and VOCs emitted from power plants, industries and automobiles. Principal constituents of particulate matter include sulfate, nitrate, ammonium, organic carbon, elemental carbon, sea salt and dust (Fann et al. 2016). Particulate matter is regulated by the USEPA as mass concentrations in different size fractions: PM10 includes the mixture of PM with aerodynamic diameters of less than 10 microns, and PM 2.5 includes particles less than 2.5 microns. PM2.5 includes mainly particles arising from combustion sources and secondary particle formation, whereas PM10 includes these sources as well as crustal materials like dust and particle of biological origin such as small pollen and spores. Both PM10 and PM2.5 are so small that individual particles cannot be detected with the human eye.

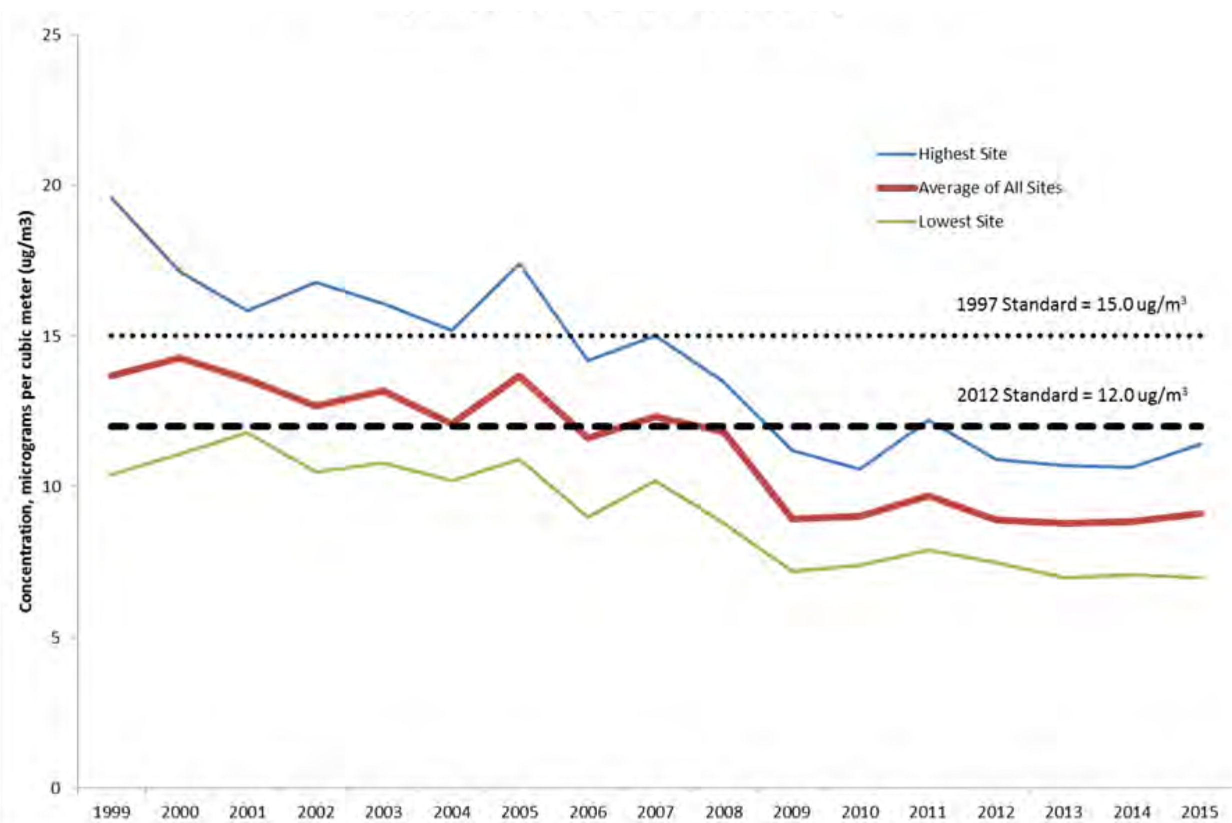
As is the case with ozone and its health effects, there is also no known threshold level below which PM air pollution does not cause adverse health effects (WHO 2016). PM2.5 is hazardous to health because it is small enough to embed itself deeply in the lungs, and can potentially make its way into the bloodstream. Inhalation of particulate matter can therefore cause a range of negative health impacts, including coughing and difficulty breathing, chronic bronchitis, heart attack, arrthymias, decreased lung function, and aggravated asthma (EPA 2015b). Additionally, these small particles can also adversely affect vegetation and aquatic ecosystems (EPA 2016).

Ambient particulate matter (PM) air pollution is a major risk factor in the global burden of disease and approximately 3.1 million deaths worldwide have been attributed to ambient PM exposure (Lim et al. 2010). PM has been associated with increased rates of respiratory and cardiovascular disease, as well as premature mortality (Brook et al. 2010 and Hoek et al. 2013). There is also a growing body of evidence that links PM exposure to adverse pregnancy outcomes, metabolic disease, and cognitive impairment (Wang et al. 2014, Stieb et al. 2012, and Peters et al. 2015). Of particular concern is fine PM, (also known as PM2.5), which refers to particles with aerodynamic diameters smaller than 2.5 microns, which is about 1/60th the diameter of a human hair. Specifically, in NJ, fine PM exposure has been linked to increased rates of heart attacks, adverse birth outcomes, asthma, and other cardiopulmonary diseases (Rich et al. 2008, Rich et al. 2010, Faiz et al. 2013 and Gleason et al. 2014).

Previously, thirteen of NJ's twenty-one counties were designated as nonattainment for the $PM_{2.5}$ (particulate matter less than 2.5 microns in diameter) NAAQS; but, on August 13, 2013, the US EPA re-designated those counties to attainment for the annual and 24-hour NAAQS (12 and 35 ug/m3, respectively). (NJDEP 2015). However, research indicates that the community multiscale air quality (CMAQ) model, frequently used to assess the effectiveness of efforts to achieve the NAAQS, often under predicts peak summertime $PM_{2.5}$ concentrations in the eastern United States, in part due to inaccurate representation of electricity sector emissions throughout the northeastern US during peak energy demand. (Farkas et al. 2015). Such peak $PM_{2.5}$ concentrations typically occur during heat waves, when electricity demand is highest.

Reductions in emissions of particulate matter are attributed to state and federal controls on sources of emissions such as sulfates, regulatory controls on vehicles and off-road equipment, state and federal mercury and air toxics standards and rules regarding low sulfur fuel (NJDEP 2016b). Additionally, in New Jersey alone, millions of federal grant dollars have been focused on reducing emissions from non-road construction equipment and other non-road sources in NJ (NJDEP 2017a). Figure 15, below, shows the annual average concentration of PM 2.5 in New Jersey from 1999-2015. The blue line is the trend of the highest PM 2.5 Annual Average concentrations measured by a NJ monitor for that particular year and, conversely, the green line is the trend of the lowest PM 2.5 annual average concentration measured by a NJ monitor for that year, and conversely, the green line is the trend of the lowest PM 2.5 Annual Average concentrations measured by a NJ monitor for that year. The red line is the average PM 2.5 annual average concentration from all the NJ monitors.

Figure 15: Trends in Statewide Annual PM 2.5 Averages



Source: New Jersey Department of Environmental Protection (NJDEP 2017)

Black carbon (BC) is emitted into the atmosphere in the form of fine particulate matter (PM 2.5) and is estimated to account for approximately 12% of all PM 2.5 emissions in the U.S. (USEPA 2012). BC is estimated by the Intergovernmental Panel on Climate Change to be the third most important individual contributor to warming after carbon dioxide and methane (IPCC 2013). Black Carbon has long been associated with adverse health impacts such as cardiovascular and respiratory effects (USEPA 2012). Most U.S. emissions of BC come from mobile sources (52%), especially diesel engines used in onroad vehicles such as trucks and cars and nonroad equipment such as locomotives, small generators, and construction equipment. EPA reports that 93 percent of all mobile source emissions came from diesel engines in 2005. Other sources in the U.S. include open biomass burning (including wildfires) and residential and commercial heating and power plants. Federal standards for nonroad engines lag behind those for onroad engines, for which engine standards required a >90 percent reduction in PM 2.5 emissions by model year 2007. EPA notes that efforts to reduce BC through reductions in PM 2.5 and other co-pollutants including air toxics have substantial benefits to public health that often exceed the costs of control. (USEPA 2012). Black Carbon is not monitored as an individual pollutant as part of New Jersey's National Ambient Air Quality Standard monitoring network. The major sources of diesel particulate matter in New Jersey are on-road and off-road vehicles powered by diesel engines (NJDEP 2017b). In addition to cars, trucks, and buses, diesel engines are used in construction vehicles, agricultural equipment, trains, and marine vessels. Diesel engines are also used to generate electricity on both an emergency and routine basis, and are also found on cranes, drilling equipment, and portable pumps. (NJDEP 2017b).

The impact of climate change on particulate matter emissions is more complex than that for ground-level ozone because the impacts of meteorological factors can have competing impacts on different particulate matter components, though some general conclusions can be drawn from the research done to date. Particulate matter is a mixture of many components, including sulfate, nitrate, ammonium, organic carbon, elemental carbon and dust, and impacts are difficult to categorize when grouping PM species together. Studies consistently show that climate change will lead to increases in sulfate concentrations, but decreases in nitrate concentrations in the Northeastern U.S. (Dawson et al. 2014). Consequently, the research indicates that the differences in net PM concentrations brought on by climate change alone will be small on average (Jacob et al. 2009). Additionally, as particulate matter can be removed from the air by rainfall, it is uncertain as to how changes in precipitation will affect particulate matter concentrations. Similarly, it is uncertain as to how anticipated changes in stagnant air episodes and wind patterns may affect particulate matter concentrations in outdoor air (USGCRP 2016).

Although modeling studies to date indicate that changes in meteorological variables attributable to climate change will cause relatively small increases in ambient PM concentrations due to direct effects of changes in meteorological variables from climate change, other intermediate factors could result in greater net increases. Droughts brought on by climate change are expected to increase the frequency of wildfires, and this could drive increases in PM emissions. Furthermore, the frequency, intensity, and duration of stagnation events (e.g., when an air mass remains in an area over an extended period and pollutants are not cleared because of light winds) are expected to increase with climate change, and this has been noted to be particularly true for the eastern United States (Horton et al. 2012). Future stagnation is thought to be associated with an increase in PM in densely populated regions (Jacob et al. 2009) and such stagnation events often occur during heat waves when electricity demand is highest due to air conditioning load and associated PM emissions from coal fired power plants in regions upwind of NJ.   Two more coal plants have recently closed in New Jersey, which should result in concomitant reductions in GHG emissions as well as PM and ozone concentrations (Johnson 2017).

Another important consideration with regard to anticipating public health impacts of climate change due to outdoor air exposure is that, with increasing temperatures, electricity demand for air conditioning use is expected to increase which, in turn, will increase emissions of pollutants, such as ozone precursors and particulates, which can affect health outcomes (NJDOH 2013, NYDOH 2011). Analyses of measured air quality data for New Jersey show that increases in both particulate matter (PM2.5) and ozone can exceed national air quality standards during high electricity demand days (Farkas 2016).

Aeroallergens

Changing climate conditions can affect the production, distribution and timing of airborne substances that cause allergic responses such as pollen, mold spores, dust mites and dander. Allergic responses can cause worsening of asthma, allergic rhinitis (hay fever), and other respiratory conditions in sensitized (allergic) individuals. These health outcomes may have the greatest impact on young children and the elderly. Although the causes are largely unknown, hay fever prevalence in the U.S. has increased from 10% of the population in 1970 to 30% in 2000 and asthma rates have increased from approximately 8 to 55 cases per 1,000 persons in 1970 to approximately 55 to 90 cases per 1,000 persons in 2000. (USGCRP 2016).

Allergic disease with skin or respiratory symptoms can include eczema, allergic rhinitis, and asthma, which all contribute significantly to disease burdens in New Jersey. The prevalence rate for asthma in New Jersey is 9% among adults and 9% among children (NJDOH 2017a). Whether or not exposure to aeroallergens is related to sensitization and development of allergic disease is an active area of research. Studies examining season of birth, as well as pollen exposure prenatally and during early life have linked these exposures to sensitization and disease development; however, the results remain unclear (Sheffield et al. 2011). On the other hand, it is clear that aeroallergens, such as pollen and mold, both indoors and outdoors, can exacerbate symptoms of allergic disease in those already affected Sheffield et al. 2011). The direction and magnitude of health effects may depend on the type of pollen or mold that the population is exposed to.

A study conducted in New Jersey during the warm season (defined as April through September) for 2004-2007 examined the relationship between pediatric asthma emergency department visits and ozone, PM2.5, several types of pollen (tree, grass and weed), and ragweed. The study found positive associations for four variables: ozone, PM2.5, tree pollen and weed pollen. However, there was a negative association with ragweed and the association with grass pollen was minimal. The authors concluded ozone in their study to be associated with increases in pediatric emergency department asthma visits during the warm weather season and that while different pollen types showed different associations, high levels of tree pollen appear to be an important risk factor in asthma exacerbations (Gleason et al. 2014).

Some studies indicate that rising temperatures and increased CO2 production could lengthen the ragweed pollen season and increase pollen abundance and potency, increasing the likelihood of allergenic diseases such as allergic rhinitis (USCCSP 2008; Bielory et al. 2012). Extreme rainfall and rising temperatures can foster the growth of indoor fungi and molds, leading to increased risk of respiratory and asthma-related conditions (USGCRP 2013). Studies of the effects of climate change on aeroallergens have focused on pollen and mold spores. Climate change may increase both the quantity of pollen productions as well as the allergenicity of pollen (Bielory et al. 2012). In a controlled environment, ragweed plants grown at pre-industrialization CO_2 levels were compared to plants grown at then-current CO_2 levels, and to ones grown at projected 21st century CO_2 levels and results suggested that rising CO_2 would cause an increase in ragweed pollen production (Ziska et al. 2000). Another study found that there has been a significant increase in the duration of the ragweed pollen season in North America since 1995 (Ziska et al. 2011). Several studies have shown that higher temperatures and greater precipitation can lead to increased pollen production (Sheffield et al. 2011).

Indoor air quality

Changing climate conditions can affect indoor air quality as a result of changes to outdoor conditions that affect indoor ones, reduced dilution of indoor air by outdoor air, as well as the increase in conditions that support the spread of pests, disease vectors and infectious agents. Poor indoor air quality affects respiratory and other health affects since, on average, people spend 90% of their time indoors. Pollutants affected by climate and weather conditions that may enter indoor air spaces from outdoors may include ground level ozone, dust, pollen and fine particulate matter. Climate-related impacts resulting in increased drought and dust storms may increase concentrations of dust and dust-carried pathogens such as bacterial and fungal spores in indoor air. For example, diseases such as Legionnaires' are contracted from water-borne bacteria in building cooling systems which can increase in warmer conditions. Pollutants generated indoors may include carbon monoxide (CO), formaldehyde, molds, pollen and other known contaminants that can affect health. As dampness increases indoors from severe weather events and/or changes to outdoor humidity, concentrations of indoor pollutants may increase. Power outages from more frequent extreme weather events could make it difficult to maintain indoor temperatures and humidity leading to increases in indoor mold growth and increases in indoor air pollutants such as volatile organic compounds and formaldehyde. Additionally, changing climate conditions may lead to increases in rodent populations as well as drive rodents to indoors increasing exposures to rodent-related allergens (Fann et al. 2016).

Extreme Heat

As average temperatures continue to rise in the Northeast, heat waves are expected to increase in both frequency, intensity and duration (Horton et al. 2014). Exposure to extreme heat can result in heat stress (USCCSP 2008), which manifests itself in several ways including heat stroke, heat exhaustion, heat syncope (fainting), heat cramps, or heat rashes (CDC 2012). In more extreme circumstances, exposure to extreme heat can cause stroke and even death (Gronlund et al 2014; CDC 2013a). Extreme heat is already the leading cause of weather-related death in the United States; from 1999-2003, 3,442 deaths were reported as a result of excessive heat (Luber and Conklin 2006). The extreme heat wave experienced by Europe in the summer of 2003 caused more than 70,000 excess deaths (Robine et al. 2008), showing the extent to which extreme heat can have an impact on public health without proper systems in place. New Jersey data for 1999 and 2002, two of the hottest summers on record in the State report 30 cases of heat-related mortality in 1999 and 18 in 2002 (NJDHHS 2008b). According to the New Jersey Department of Health and Senior Services, "each year more than 1,200 persons are treated in New Jersey emergency departments for heat-related illness or sunburn, and overexposure to summer heat causes between 45 and 170 hospitalizations in New Jersey annually. The majority of those hospitalized in New Jersey are male, ages 65-84, and are hospitalized for 3 or more days" (NJDHHS 2008b).

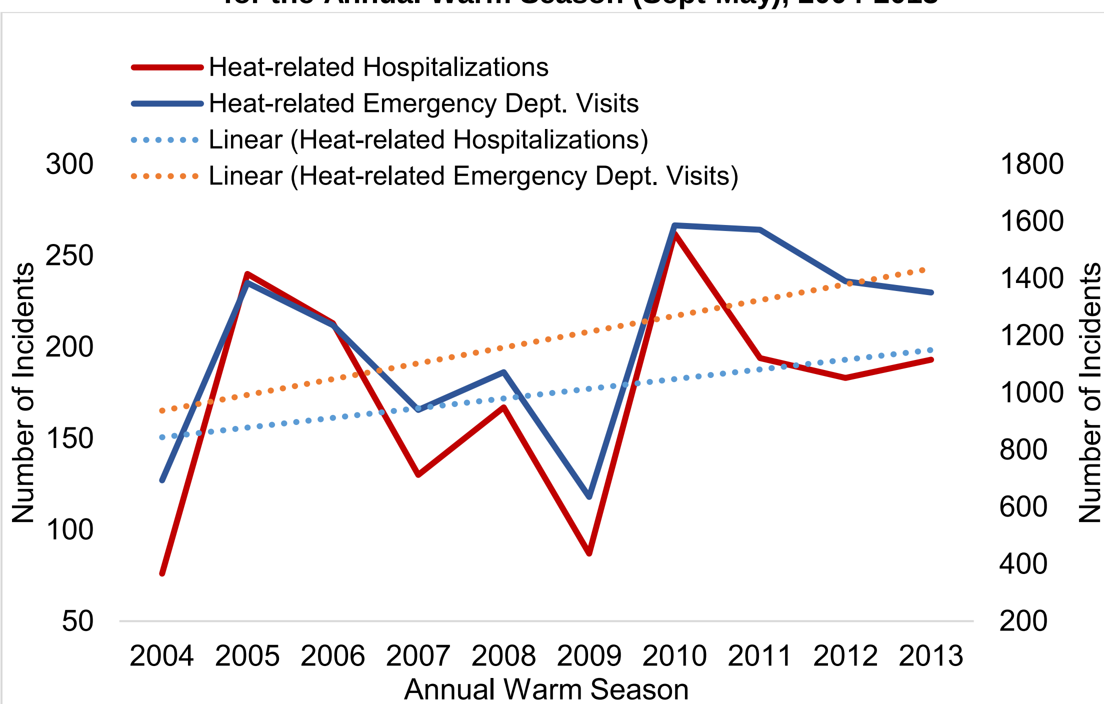
New Jerseyans are at the highest risk for heat-related illness during the "warm season", which extends from May through September—with peak temperatures occurring in June and July. Heat-related illness data obtained from the New Jersey Department of Health (NJDOH 2015b) for the warm season for the years 2004 through 2013 show that the number of heat-related illnesses have been rising over the past decade (see Figures 16 and 17).

Figure 16: Adjusted Rates per 100,000 of Heat-related Illness by Region for the Warm Season (May-Sept), 2004 versus 2013

Regional Hospital Admissions, Age-Adjusted Rates for 2004 and 2013				
	2004	**2013**	**Rate Increase**	**Percent Increase**
Central	0.7	1.9	1.2	171%
Coastal	1.7	3.1	1.4	82%
Northern	0.4	1.2	0.8	200%
Pine	1.1	2.5	1.4	127%
Southern	1.2	3.6	2.4	200%
Regional ED Visits, Age-Adjusted Rates for 2004 and 2013				
	2004	**2013**	**Rate Increase**	**Percent Increase**
Central	6.8	13.7	6.9	101%
Coastal	11.3	23.1	11.8	104%
Northern	6.8	12.3	5.5	81%
Pine	9.4	19.0	9.	101%
Southern	9.5	16.0	6.5	68%

Rates have been adjusted to take into consideration age and total population for each geography.
Data source: NJDOH, 2015

Figure 17: Total Number of Heat-related Hospitalizations and Emergency Department Visits for the Annual Warm Season (Sept-May), 2004-2013



Data source: NJDOH, 2015b

Heat-related illness counts include both hospitalizations and emergency department visits. Hospitalizations are more serious, less frequent cases that require hospital admission while emergency department visits are less serious, more frequent cases. Rates of heat-related illness emergency department visits and hospitalizations by county and region show a wide variation across the state. Between 2004 and 2013, the Coastal Region experienced the greatest increase in heat-related emergency department visits, more than doubling. However, the Southern Region experienced the greatest increase in hospitalization over this time period. As shown in Figures 18a and 18b, 2013 rates by county reveal that Middlesex and Somerset Counties are among the areas with the lowest rates of both heat-related hospitalizations (0.99 and 0 per 100,000, respectively) and heat-related emergency department visits (9.8 and 8.0 per 100,000) while Ocean and Salem Counties are among the highest (hospitalizations at 3.8 and 4.5 per 100,000, respectively; emergency department visits at 22.4 and 21.2 per 100,000, respectively) (NJDOH 2015b).[2]

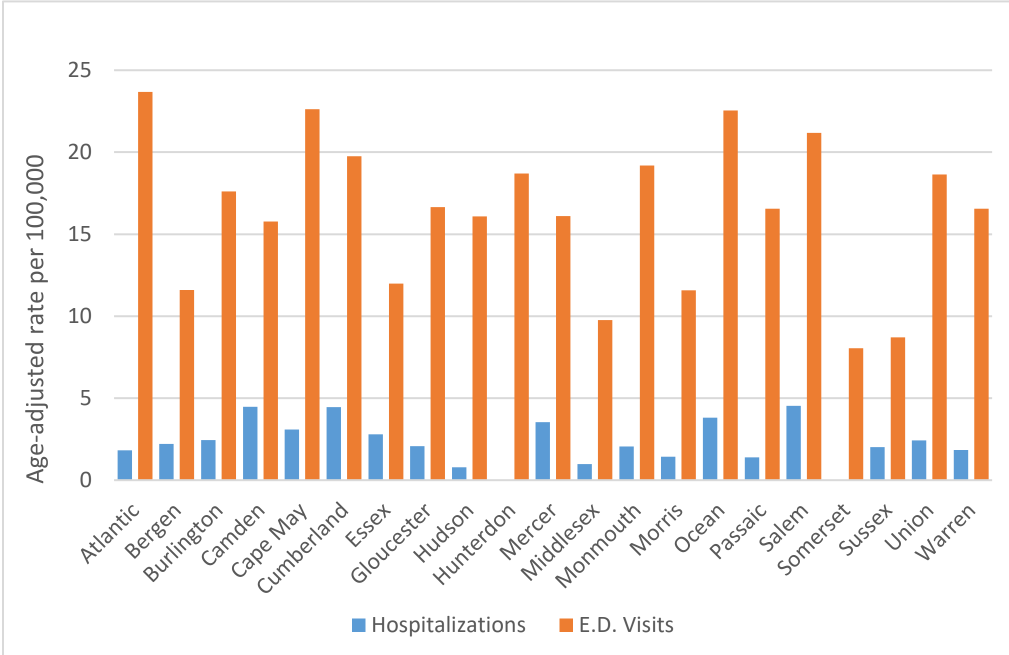
Figure 18a. Age-adjusted Rate of Heat-related Illness (per 100,000) Data for the 2013 Warm Season (May-September), By County

County	Hospitalizations	E.D. Visits
Atlantic	1.82	23.68
Bergen	2.21	11.60
Burlington	2.45	17.61
Camden	4.48	15.77
Cape May	3.08	22.62
Cumberland	4.46	19.76
Essex	2.81	11.99
Gloucester	2.08	16.65
Hudson	0.79	16.08
Hunterdon	0.00	18.70
Mercer	3.55	16.10
Middlesex	0.99	9.75
Monmouth	2.06	19.19
Morris	1.42	11.58
Ocean	3.82	22.55
Passaic	1.40	16.56
Salem	4.54	21.19
Somerset	0.00	8.04
Sussex	2.01	8.71
Union	2.42	18.64
Warren	1.84	16.56

Source: NJDOH 2015b

[2] The age-adjusted rate of heat-related hospitalizations for Middlesex and Somerset counties were among the lowest in the state at 0.99 and 0 per 100,000 respectively. Heat-related ED rates for these two counties were also among the lowest in the state at 9.8 and 8.0 per 100,000 respectively. The age-adjusted rates of heat-related hospitalizations for Ocean and Salem counties were among the highest in the state at 3.8 and 4.5 per 100,000 respectively. Heat-related ED rates for these two counties were also among the highest in the state at 22.5 and 21.2 per 100,000 respectively.

Figure 18b. Age-adjusted Rate of Heat-related Illness (per 100,000) Data for the 2013 Warm Season (May-September), By County



Source: NJDOH 2015b

Two existing studies demonstrate the relationship between heat-related illness, temperature, and heat index for New Jersey The first, a statewide study conducted by the New Jersey Department of Health, analyzed heat-related illness data for New Jersey between 2010 and 2011. Results of the study showed that daily heat-related illness counts increased as heat index values increased, with similar patterns observed across all regions of the State. Further, the ratios of daily heat related illness counts and heat index levels were greatest at heat index values of 100-102°F and 109°F and higher (Fagliano et al. 2013). The second, a national study conducted across 20 states by the CDC's Environmental Public Health Tracking Program, found strong correlations between heat-related illness hospitalizations and both average monthly maximum temperature and average maximum heat index. New Jersey had one of the most pronounced effects of any Northeastern state in the study (Choudhary and Vaidyanathan 2014). Data for both studies were limited to the "warm season", defined as May through September.

Heat can also exacerbate existing chronic health conditions, including cardiovascular, respiratory, and cerebrovascular diseases and diabetes-related conditions and has been shown to increase the risk of kidney stones and renal failure (USCCSP 2008; Sarofim et al. 2016; USCCSP 2008; Semenza 1999). Diabetics have an increased risk of heat-related mortality, as do people on certain medications, particularly diuretics, which have a dehydrating effect (USGCRP 2009; Schwartz 2005). Elderly people are especially susceptible to heat-related morbidity and mortality (Basu 2005). Urban heat islands may increase heat-related health impacts for city dwellers by “raising air temperatures in cities 2-10°F over surrounding suburban and rural areas due to lack of vegetation and absorption of heat by paved surfaces and buildings,” (USCCSP 2008). Other indirect health effects include infrastructure failures like power outages, a strain on emergency and health care services, in particular 911 response and emergency department demands, inability to have access to air conditioning and water treatment, and general impacts on mental health and stress. (MDH 2015).

Extreme Precipitation and Storms

The intensity of extreme storm events is increasing and is projected to increase further in the Northeast through the end of the century (Horton et al. 2014). Extreme precipitation and storm events can include events such as hurricanes and floods which result in both direct and indirect health impacts. Acute precipitation and storm-related health impacts include direct morbidity and mortality from drowning, downed trees, and carbon monoxide poisoning, food and water contamination in the wake of storm events, and lack of availability of medicines and medical equipment as a result of power outages and business closures. Chronic issues resulting from storm events include mental health impacts and the health effects of mold exposure (NJCAA 2013). An estimated 2,544 people died in the United States or its coastal waters from tropical cyclones in the 50-year period of 1963 to 2012. Approximately 90% of these deaths occurred in water-related incidents, mostly drowning (Rappaport 2013).

Extreme rainfall events can also affect raw water quality by increasing turbidity and bacteriological contaminants leading to gastrointestinal (GI) illnesses. In New Jersey, a statewide study done on hospitalization data for GI illnesses between 2009 and 2013 revealed a positive association between extreme rainfall and GI hospitalizations during the warm season and that study participants residing in an areas served by surface water on the day of an extreme rainfall event were at increased risk, as opposed to those residing in areas served by ground water or “other” water source (Gleason 2015).

Hurricane Sandy demonstrated the wide range of health impacts that can result from widespread flooding and power outages when it hit the east coast of the United States in October 2012. The death toll in New Jersey as a result of Hurricane Sandy was 34; total death toll from the storm was 117 across U.S. states affected by Sandy (NJCAA 2013). Several studies were conducted in New Jersey post-Sandy to examine the health impacts of the storm. One such study examined hospitalization and emergency department utilization for respiratory complications (chronic obstructive pulmonary disease and asthma) in adults over age 60 to ascertain the vulnerability among individuals with chronic conditions requiring ongoing management with medications and electrical medical equipment during severe weather events. Thomas et al. (2015) report an increase in both emergency department visits and hospitalizations for these respiratory complications during the Sandy Period (defined as the two-month period starting the day prior to Sandy's landfall) compared with pre-hurricane rates and also compared with the same two-month period for the prior four years. They also reported that older women in poorer and minority neighborhoods were especially vulnerable (Thomas et al. 2015). Another study found similar results when analyzing the number of preventable hospitalizations for complications of diabetes following the storm; the authors note such hospitalizations result from inappropriate or interrupted ambulatory care (Rajan et al. 2015).[3] The same study reported significantly higher rates of preventable complications from diabetes during the Sandy period compared with the pre- Sandy period or for the same period in the four years prior to the study; they also found that the rates were significantly higher in lower socioeconomic status communities than higher socioeconomic status communities (Rajan et al. 2015). These analyses demonstrate that extreme weather events can easily disrupt the management of chronic conditions like COPD, asthma, and diabetes.

Widespread power outages, gas shortages, and flooding after extreme weather events, including hurricanes, is also cause for concern as they can result in toxic exposures and unintentional misuse of medicine. These public health threats should be taken into consideration when evaluating the impact of an increased number of extreme storms. One study measured the calls made to the New Jersey Poison Control Center, also known as NJPIES, in the days immediately preceding, during, and after Hurricane Sandy to determine opportunities for targeted public health education and intervention. The two most frequent reasons for Sandy-related NJPIES calls in 2012 were for gasoline (32%) and carbon monoxide (20%) exposures. The three most other frequent Sandy-related exposures or information were poison information, food poisoning and spoilage information; and water contamination/information. Over 80% of both gasoline and carbon monoxide exposures occurred at the patient's own residence. These findings point to a need for enhanced public health education and intervention in New Jersey, including proper use of gasoline-powered generators and cleaning and cooking equipment (German 2015).

New Jersey's experience with Superstorm Sandy demonstrates that development of indoor mold can be a particular health concern after a major storm. In a survey of more

[3] Note: "preventable" hospitalizations are defined as: "admissions to a hospital for certain acute illnesses (e.g., dehydration) or worsening chronic conditions (e.g., diabetes) that might not have required hospitalization had these conditions been managed successfully by primary care providers in outpatient settings. (CDC 2011)

than 300 residents in NJ shore communities, 19% of respondents reported mold in their homes after Sandy, while only 8% had experienced this problem before Sandy (Burger et al. 2014). While the majority of respondents stated that they used professional services for mold remediation, of those that did not, many did not use proper personal protective equipment and fewer than 20% used respirators (Burger et al. 2014). Although safety information was available, it did not reach the intended audience in many cases.

Decreases in precipitation can also result in significant health risks—both direct and indirect. Droughts increase the risk of wildfires, which may increase the potential for widespread ecological and infrastructural damage, as well as mortality (Cannon et al. 2003). Wildfires may also increase the risk of particulate matter in the air (Haikerwal et al. 2015), increasing the risk of associated respiratory problems. Dry conditions and porous soil in the Pine Barrens region of New Jersey make the area particularly vulnerable to wildfires (Ludlum 1983). In September 2015, lack of precipitation was cited by the New Jersey Department of Environmental Protection as a contributing factor to the spread of a wildfire, initially ignited by improper disposal of campfire, which burned over 1,000 acres of Pine Barrens forests (Alexander 2015; NJFFS 2015).

Droughts can contribute to the levels of airborne particulate matter as these conditions increase the risk of wildfire and dust storms. In both cases, there is an increased likelihood of particulate matter being suspended in the air, which poses a risk to respiratory health (CDC 2015). Extreme conditions like droughts can also have a significant impact on crops and livestock, negatively impacting agricultural production and threatening the security of our food supply (Horton et al. 2014). In addition to food insecurity, a decrease in agricultural sector productivity could amount to significant economic loss. Agricultural commodities in the United States is a nearly $330 billion a year industry (Horton et al. 2014). In New Jersey, this sector is the state's third largest industry and generates billions of dollars in revenue (NJDA 2012).

Ecosystem Changes and Threats

Changing climate conditions have the potential to significantly affect the function of ecosystems resulting in direct and indirect impacts to public health, including impacts associated with vector-borne and zoonotic diseases, food and water-borne diseases, and availability of water supply.

As temperatures and humidity rise, certain vector-borne and zoonotic diseases are expected to expand their ranges, including tick-borne illnesses such as Lyme disease, ehrlichiosis, babesiosis, Powassan, and Rocky Mountain spotted fever; rodent-borne hantavirus; and mosquito-borne diseases such as West Nile virus and Eastern and Western equine encephalitis (CDC 2013b; USCCSP 2008). The range of the Asian tiger mosquito, an invasive species with high vector disease potential, continues to expand further north in the Northeastern United States; by the end of the century approximately 30 million Americans will live in areas at risk of dense Asian tiger mosquito infestations (Rochlin et al. 2013). The Asian tiger mosquito is a primary vector for dengue and chikungunya fevers, the latter of which is an emerging disease in the Caribbean that has shown rapid transmission potential (Faraji 2014).

An increase in precipitation and extreme weather events increases the risk of contracting food- and water-borne diseases. “Heavy rain and flooding can contaminate certain food crops with feces from nearby livestock or wild animals, increasing the likelihood of food-borne disease associated with fresh produce” (USGCRP 2009). Flooding also increases the likelihood of drinking contaminated water, which can lead to an increased incidence of gastrointestinal illness. The waterborne Cryptosporidium and Giardia parasites tend to increase in the aftermath of heavy downpours, putting recreational swimmers at higher risk of gastroenteritis (USCCSP 2008). Power outages resulting from severe weather events increase the likelihood of consuming spoiled food. Cases of food poisoning due to Salmonella have been shown to increase with increasing air temperatures, making it likely that increased average temperatures and more frequent heat waves will result in more cases of salmonella. Vibrio, the pathogen responsible for shellfish poisoning, shows a similar positive relationship with warmer temperatures; from 1996 to 2006, the U.S. infection rate increased by 41 percent. The Campylobacter bacteria, responsible for 29% of water-borne outbreaks, has shown a positive but less conclusive relationship with rising temperatures. Increasing temperature may increase the range of leptospirosis, a currently rare bacterial infection typically transmitted through urine contaminated water, while increasing precipitation and run-off makes transmission of leptospirosis more likely (USCCSP 2008). A general challenge posed by food and water-borne diseases is that these incidences tend to be highly underreported, making recognition of disease patterns and administration of proper treatment more difficult for the public health sector (USCCSP 2008).

The Legionella bacterium, is found in freshwater environments and grows best in warm water (CDC 2015). Gleason et al. (2016) conducted a statewide study of legionellosis in New Jersey analyzing the effects of meteorological factors including temperature, dew point, sea level pressure, visibility, wind speed, and precipitation on the number of reported cases. This study revealed positive associations of rates of legionellosis with indicators of wet, humid weather and inverse associations with high sea level pressure and high visibility (which are indicative of fair weather) (Gleason et al. 2016). The authors concluded that it is possible that wet, humid weather may allow proliferation of Legionella in natural environments increasing the rate of legionellosis (Gleason et al. 2016).

Sea-level rise and increased drought occurrence can increase the salinity of both groundwater and surface water sources of drinking water. In combination with increased groundwater pumping to meet demand, sea-level rise can exacerbate saltwater intrusion increasing the salinity of groundwater aquifers and well water. The result may be unusable groundwater wells, and advanced encroachment of saltwater upstream to drinking water supplies. In addition to causing increased cost for water treatment and the possible need to identify alternative sources of fresh water, increased salinity of drinking water supplies can increase the risk of hypertension and diarrheal disease (USEPA 2017).

A report prepared on behalf of the New Jersey Climate Adaptation Alliance identifies several aquifer locations that are vulnerable to increased saltwater intrusion from sea-level rise: The Monmouth Bayshore area (along the Raritan Bay) and the Gloucester/Camden County area (along the Delaware River), are already subject to withdrawal limitations to reduce the potential for saltwater intrusion. At the southern end of Cape May County, saltwater intrusion has already resulted in abandonment (for direct use) of public wells in Cape May City and threats to wells in Lower Township along the Delaware Bay. Two other areas of concern identified by the report are the northern outcrop area of the Atlantic City 800 Foot Sands in southern Ocean County and the Delaware Bay area in Cumberland and Salem Counties, where the exceptionally flat topography creates the potential for extensive saltwater intrusion through the marsh areas (Van Abs 2016).

Climate Change Impacts on Mental and Behavioral Health

Research is increasingly pointing to the impacts of climate change on mental and behavioral health. A recent report from the American Psychological Association found that efforts to consider climate change impacts to mental health have been secondary to physical health. The report finds that "major acute mental health impacts include increases in trauma and shock, posttraumatic stress disorder (PTSD), compounded stress, anxiety, substance abuse, and depression. Climate change– induced extreme weather, changing weather patterns, damaged food and water resources, and polluted air impact human mental health. Increased levels of stress and distress from these factors can also put strains on social relationships and even have impacts on physical health, such as memory loss, sleep disorders, immune suppression, and changes in digestion. Major chronic mental health impacts include higher rates of aggression and violence, more mental health emergencies, an increased sense of helplessness, hopelessness, or fatalism, and intense feelings of loss." The report concludes that building resilient, socially cohesive communities is essential to address the physical and mental health impacts of climate change and that doing so enhances the resilience capacity of communities as well as individuals (Clayton et al. 2017).

Section VI: Vulnerable Populations

This section reviews which of New Jersey's population subgroups are likely to be particularly vulnerable to the health impacts of climate change hazards discussed in Section 5 (Causal Pathways) of this report. While climate change is likely to affect everyone, not all subgroups will be equally affected. Climate change disproportionately affects some populations and communities making them less able than others to adapt to or recover from climate change impacts. Factors affecting these populations can include: where they live; having preexisting exposures to multiple risk factors compared to other groups; having limited access to healthcare services and health insurance; having limited availability to access helpful information in a person's native language; and having less ability to relocate or rebuild after a disaster (USEPA 2016c). New Jersey is one of the top three most diverse states in the country with respect to race and ethnicity and foreign-born populations, which poses important challenges to delivery of public health systems (NJDOH 2015a). In a diverse population like that of New Jersey, it is important to understand the way risk and vulnerability vary across groups in order to target prevention and intervention strategies appropriately. Understanding how factors, such as health inequities and disproportionate levels of environmental pollutants, relate to climate change impacts can inform development of meaningful public health policies and interventions. (USGCRP 2016).

Climate change may amplify, moderate or otherwise influence climate-related health effects among populations that are experiencing disproportionate, multiple and complex risks to their health and well-being particularly if these effects co-occur. Although this section is structured by distinct categories of climate-related exposures, these exposures can co-occur. Some communities of color, low-income groups, people with limited English proficiency and certain immigrant groups (especially those who are undocumented) live with many of the factors that contribute to their vulnerability to climate-related health impacts and affect their ability to respond to climate change. These populations are at increased risk of exposure given their higher likelihood of living in risk-prone areas (e.g., urban heat islands or flood-prone areas), areas with older or poorly maintained infrastructure, or areas with higher levels of air pollution. Such populations are known to experience relatively greater incidence of chronic medical conditions, like cardiovascular and kidney disease, diabetes, asthma, and chronic obstructive pulmonary disease, which can be exacerbated by climate-related health impacts (Gamble et al. 2016).

Air Quality

Populations vulnerable to experiencing negative health outcomes related to poor air quality include children, people with respiratory health conditions, urban residents and residents with limited access to health care. In its 2015 'State of the Air' Report Card of New Jersey, the American Lung Association ranked the air quality of 15 counties in New Jersey based on the number of high ozone days per year. Eleven of these counties received Fs, indicating that air quality throughout New Jersey is already a health problem (ALA 2015). As temperatures increase and ozone increases, populations in densely populated urban areas with poor air quality are also subject to the urban heat island effect (where manmade surfaces absorb sunlight during the day and then radiate the stored energy at night as heat), combining to increase impacts of high temperatures in urban areas (Sarofim et al. 2016).

Outdoor workers, which include laborers employed in agriculture, construction, maintenance, and repair, make up nearly 10% of New Jersey's workforce (Bureau of Labor Statistics 2011). People employed in these occupations are at greater risk of negative health impacts from increased ozone and particulates due to their greater level of exposure. Asthma effects 9% of New Jersey adults and about 9% of New Jersey children; however, according to the New Jersey Department of Health, there are significant disparities in asthma burden among specific populations with black adults having the highest prevalence at 14% (NJDOH 2017a). Research indicates that increases in the levels of pollen in the air result in more asthma-related hospital admissions among New Jersey children (Im and Schneider 2005).

A longer pollen season in New Jersey is already putting people at increased risk of allergic disorders. Coupled with the warming effects of climate change, which may cause increased pollen counts and potency, it is anticipated that asthma and allergy-related hospital admissions are likely to increase in New Jersey, especially among children (NJCAA 2014). People with existing heart and lung diseases, as well as children and older adults, are also more susceptible to the effects of PM2.5 (NJCAA 2014).

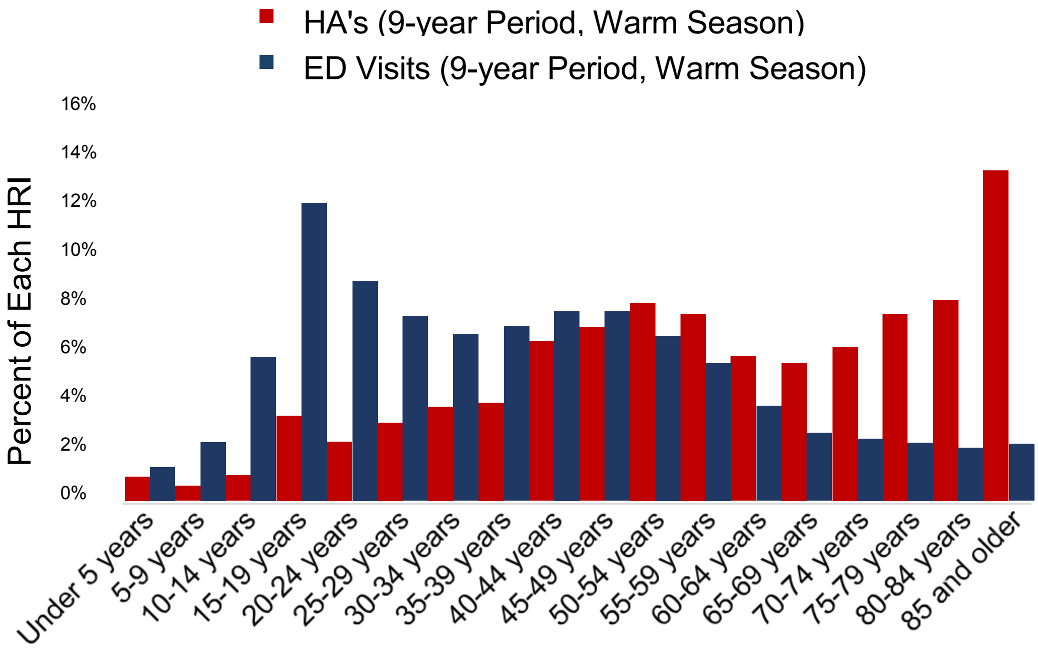
Residents in urban areas can be subject to cumulative impacts from multiple sources of air pollution in addition to ozone and particulate matter. Hazardous air pollutants, known as "air toxics" pose greater risks in urban areas due to higher concentrations of emissions sources. The United States Environmental Protection Agency has identified 187 air toxics with 30 of them being of greatest concern in urban areas. Exposures to localized sources of pollution such as operating industries and power plants, as well as from mobile sources, can add to the cumulative impact of climate change faced by populations already vulnerable to changing climate conditions, including low-income residents and people of color that live in urban communities (USEPA 2016b).

Overall statewide trends may not represent localized poor air quality, such as in urban communities, which is an important consideration when anticipating public health impacts of changing climate conditions given that research has pointed to populations that are especially vulnerable to climate impacts. For example, in one study, research that focused on PM 2.5 and ozone found that non-Hispanic blacks reside in areas with the poorest air quality suggesting that areas of the United States have limited localized monitoring data and that populations vulnerable to climate change may experience poorer air quality (Miranda 2011). To promote overall improvements in health outcomes of people who are vulnerable to climate impacts, such as residents in urban areas, the Environmental Justice Advocacy community has strongly urged climate change policies that have a strong focus on reducing localized air pollutants in urban communities, including reducing emissions of PM 2.5 and investing in energy conservation and renewable energy in urban areas (Sheats 2009).

Extreme Heat

Individuals with existing chronic health conditions - including cardiovascular and respiratory conditions and diabetes - are vulnerable to the effects of rising temperatures, as heat can exacerbate these conditions (USCCSP 2008; Schwartz 2005). Individuals on medications, which have a dehydrating effect, particularly diuretics, are also vulnerable to high heat (USGCP 2009). Elderly people, who make up 14% of New Jersey's population (U.S. Census Bureau 2010), are especially susceptible to heat- related morbidity and mortality, as are young children, obese individuals, those lacking access to air conditioning, and outdoor laborers (USCCSP 2008). According to heat- related illness data obtained from NJDOH for the warm season 2006-2013, the majority of heat-related hospitalizations (69%) and emergency department visits (63%) are male patients, suggesting that men may be more prone to heat-related illness than women (NJDOH 2015b). Additionally, there appears to be an inverse age effect, with young teens and adults (15 – 24 years) making up a greater portion of heat-related emergency department visits and senior citizens (75 and older) making up a greater portion of heat- related hospitalizations (see Figure 19).

Figure 19: Total Heat-related Hospitalizations (HA) and Emergency Department Visits (ED) for the Warm Season (May-September), 2004-2013 (aggregated) by age group



Data source: NJDOH, 2015b - Note that because Hospitalizations are outweighed by Emergency Department Visits, data is presented as the percentage of each Heat Related Illness (i.e. Hospitalizations shows the percent for each age group out of all Hospitalizations over the analysis period).

As noted, New Jersey's urban residents, who may be subject to the urban heat island effect, or the tendency of paved surfaces and buildings that lack green space to absorb more heat (USCCSP 2008), are at a particular vulnerability to heat-related impacts compounded by warming from climate change. According to the U.S. Census, "New Jersey is the most heavily urbanized state, with 92.2 percent of its population residing within urbanized areas of 50,000 or more," (U.S. Census Bureau 2010), making the urban heat island effect especially relevant to public health in New Jersey.

Cooling centers in New Jersey are operated by municipalities (NJDHSS 2008b). While resources such as nj211.org compile lists of open cooling centers statewide, it is not clear there is statewide coordination and whether lessons learned are shared among operators of such centers. New Jersey has several cities with high concentrations of low-income residents, such as Newark (Essex County), Camden (Camden County), and Patterson (Passaic County) (U.S. Census Bureau 2010). These counties accounted for nearly 20 percent of all heat-related emergency department visits during the warm season 2004-13 and 25 percent of heat-related hospitalizations during this time period.
Note however, that the local health departments in some of these areas have strong outreach programs, whereas the public health infrastructure may not be as well developed in suburban areas. Additionally, elderly residents in suburban areas who do not have

access to cars and do not have family members living nearby may be at risk during heat waves (NJCAA 2014).

Finally, the foreign-born population of the State continues to increase, with 21% of New Jersey's population made up of immigrants in 2010 (Migration Policy Institute 2012). With over 30 languages spoken in the State (Migration Policy Institute 2012), any outreach efforts aimed at reducing heat-related morbidity and mortality must target diverse populations appropriately.

Precipitation Changes and Storms

FEMA's 2004 Map Modernization Business Plan for New Jersey, indicates that approximately 35 percent of New Jersey residents live in floodplains (FEMA 2004). The State of New Jersey indicates that the percentage would most likely be higher if updated today given an increase in definition of areas considered to be special flood hazard.[4] Flooding also puts communities at health risk from water contamination caused by combined sewer overflows; New Jersey has 217 combined sewer outfalls in 21 communities, including Jersey City and Newark (NJDEP 2013a). Infrastructure damage from flooding and storms can increase vulnerabilities among those with existing medical conditions, especially if damage threatens the availability of medicine or electricity to power medical equipment (NJCAA 2013). Chronic issues resulting from storm events include mental health impacts. A longitudinal study of Hurricane Sandy victims found that housing damage from the storm is associated with a risk of Post-Traumatic Stress Disorder (PTSD), and "children living in homes with minor damage were over four times as likely to be sad or depressed, and over twice as likely to have problems sleeping since the storm as were children from homes with no damage," (Abramson et al. 2015). Finally, increased exposure to mold from storm damage can exacerbate existing respiratory conditions (NJCAA 2013).

Evacuation rates are an important factor in considering populations most vulnerable to the effects of extreme storm and weather events. Residents who do not evacuate may be more likely to experience the negative effects of flooding and extreme winds including drowning, toxic exposure, poor mental health, and injuries. In New Jersey, a substantial number of residents evacuated their homes during Hurricane Sandy. The majority of evacuees evacuated after the storm made landfall and did not return to their homes for one day to one week afterward. However, a post-Sandy study in New Jersey found that females were more likely to have evacuated their homes than their male counterparts, which may suggest that future preparedness efforts should take into consideration demographic differences in educational campaigns and messaging (Kulkarni 2015).

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[4] Personal communication with Joseph Ruggieri, NJDEP; April 22, 2016.

Several studies conducted in New Jersey post-Sandy revealed that residents of lower socioeconomic status had higher rates of preventable hospitalizations and emergency department visits associated with chronic conditions like COPD, asthma, and diabetes. This suggests that residents in the poorest communities may be more likely to experience disruption in the management of chronic conditions during and following severe weather events or natural disasters. Additionally, COPD and asthma hospitalization and emergency department visits were found to be higher among women and older adults (over 75 years) as well (Thomas et al. 2015).

There is often an occupational vulnerability component associated with work-related injuries post disaster. One study conducted in New Jersey post-Sandy demonstrated this by analyzing the occurrence of work-related injuries after Hurricane Sandy compared with corresponding periods from the three previous years using emergency department and hospital discharge data (Marshall et al. 2016). The authors found that the rate of work-related injuries (falls, cut-pierce injuries, struck-by injuries, and overexertion) in Sandy's high impact areas increased post Sandy. Work-related injuries were highest among Black and Hispanic men. Results of this study also demonstrated a lag time between the storm and work-related injuries. There was an increase in injuries associated with rebuilding and recovery rather than the initial response to the storm. Occupations that may be particularly vulnerable to work-related injuries as a result of extreme weather and storms include those in construction, demolition, and related industries, as well as tree removal (Marshall, et al. 2016).

Assessing Social Vulnerability in New Jersey and Flood Risk

Pflicke et al. (2015) conducted an analysis for the NJ Climate Adaptation Alliance, which examined the social vulnerability of New Jersey's population to climate change using exposure to the 100-year and 500-year floodplain as an indicator of flood risk. The analysis builds upon the social vulnerability index or SOVI methodology of Dr. Susan Cutter, University of South Carolina, an approach that recognizes there are underlying social conditions that that affect how individuals equally affected by an event can respond and recover differently (Bickers, 2014). A number of factors identified as being correlated with high social vulnerability were included in this analysis such as race, low socioeconomic status, linguistic isolation, Hispanic ethnicity, age (seniors), and percent unoccupied housing; the analysis was conducted by census tract (Pflicke et al. 2015). As represented in Figure 20, a total of 309 out of 2,010 (15%) New Jersey census tracts were ranked as having high social vulnerability populations (Pflicke et al. 2015). Out of the total number of high social vulnerability census tracts in the State for which floodplain data were available (278), 69% percent or 193 high social vulnerability census tracts lie within FEMA's designated 100-year floodplain or the1% annual chance flood event, representing a population of 677,771 persons and an average population density of 9,574 persons per square mile; when expanding the scope to include the 500 year floodplain, these exposure values increased to 74% of areas ranked high for social vulnerability and include a population of 724,156 persons with an average population density of 9,596 persons per square mile (Pflicke et al. 2015). These data are a first approximation of those areas in the state where there are populations that may have differential ability to respond and recover to the effects of climate change associated with precipitation; further analysis would be needed to better quantify the relationship between vulnerable populations in New Jersey and the various health impacts posed by climate change.

Figure 20: Social Vulnerability in New Jersey by Census Tract

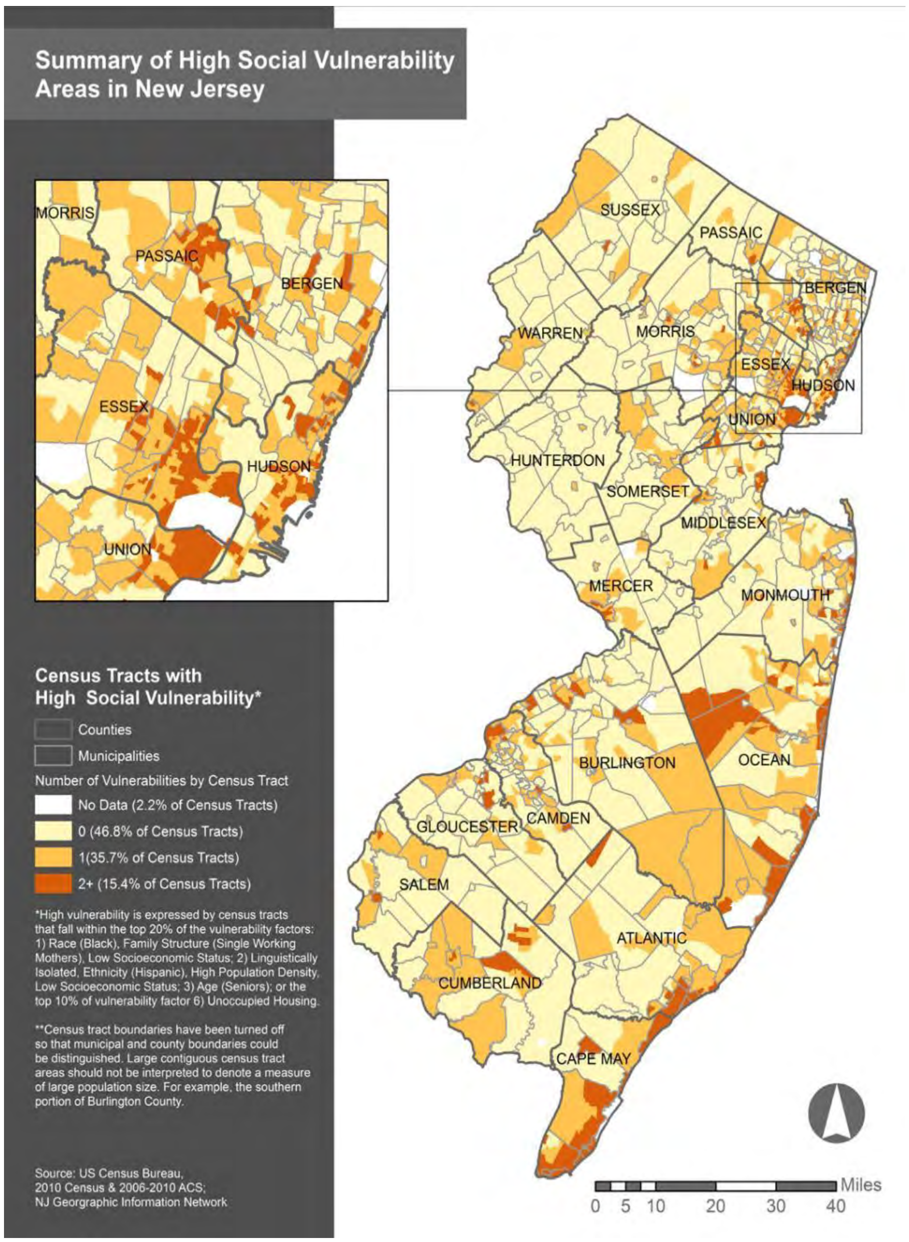


Image source: Pflicke et al 2015.

In addition, Yamanaka et al. (2015) undertook an analysis of coastal flood exposure for New Jersey's senior population to current and future sea-levels and found that Atlantic, Burlington, Cape May, Monmouth, and Salem Counties all had 50% or more of senior populations within areas of high coastal flooding exposure. Further Yamanaka et al. (2015) found that 12 out of 147 hospitals and 26 of 548 nursing homes are located within current coastal flood hazard areas in New Jersey.

Ecosystem Changes and Threats

Changes in water quality put New Jersey's coastal industries, including tourism and fisheries, at risk. Increases in waterborne disease threaten both recreational swimmers, as well as economic prospects for laborers in the fishing industry. Harmful algal blooms (HABs) are also influenced by high temperatures and precipitation changes. HABs also reduce the amount of dissolved oxygen in the water, which can lead to fish kills, affecting subsistence fishing communities and recreation (NCDHHS 2015). The elderly, very young, and those with existing health conditions may also be at particularly high risk of mortality from exposure to waterborne diseases (NCDHHS 2015).

Section VII: Next Steps

The Climate and Health Profile report is intended to provide an initial point of reference to inform a targeted set of “next steps” to incorporate conditions of a changing climate into public health planning, programs and policies in New Jersey. Along with insights gained from the New Jersey Climate Change and Public Health Workgroup’s June 3, 2016 workshop, Preparing for the Impacts of a Changing Climate on Public Health in New Jersey: A Workshop for Public Health Practitioners, the workgroup has outlined a set of next steps forward for its own efforts. In general, the Workgroup concludes that the most effective and efficient approach to protect the public health of New Jerseyans from changing climate conditions is to build consideration of changing climate conditions and the anticipated impact and consequences of those conditions into existing public health programs and systems, rather than creating a new overlay of initiatives on top of existing public health programs and services. Taking this approach involves making connections between state and local public health practitioners, health systems, climate scientists and other sectoral planners and decision-makers whose sectors influence health outcomes under changing climate conditions. Examples of the latter include hazard mitigation planners, mosquito control programs, flood plain managers, and transportation planning agencies.

As is the case in other states where concerted climate change initiatives have been adopted as part of public health practice, significant opportunities exist in New Jersey to:

- Conduct the analyses needed to identify the most pressing public health impacts of climate change in New Jersey as well as the populations most vulnerable to those impacts;
- Integrate climate science and impacts into public health planning and systems; and
- Build capacity within the State’s public health network for advancing climate change resilience, preparedness and adaptation.

This “adaptive management” approach to integrating climate change adaptation into public health practice is generally consistent with the approaches underway or under development in other states that have adopted comprehensive programs (Hess 2012). This approach recognizes the existing extensive network and organizational infrastructure that already supports public health systems, anticipates that climate change will increase current public health stressors and pose greater burden to the populations that are already most vulnerable to those stressors, and assumes that, with varying types of technical and resource support, some elements of current public health practice are well suited to respond to changing climate conditions. Adaptive management elements are intuitive to public health practice including: applying data to assess climate-related health hazards and vulnerable populations; engaging stakeholders to inform development and deployment of public health interventions; and monitoring outcomes (NRC 2004). A policy challenge facing New Jersey is to assess the extent to which current public health systems are adequately equipped to address the impacts of changing climate conditions on vulnerable populations as well as vulnerable communities, given recognized health disparities that exist in the state (NJDOH 2017).

The Workgroup has identified a five-part framework to strategically focus its efforts moving forward and it recognizes that advancing these efforts is dependent on a collaborative approach among public health practitioners, state and local decision makers, the research community, healthcare providers, and the nongovernmental community. Overall, success in advancing this framework will be measured by the extent to which changing climate conditions, and the resulting impacts from those conditions, are fully integrated into planning, decision-making and delivery of public health programs, policies and services statewide:

Act	• Implement specific actions that have already been identified as important to minimize public health risks from changing climate conditions. • Identify specific communities and populations most vulnerable to changing climate conditions and work in consultation with those populations and communities to design interventions that prioritize their needs.
Plan	• Integrate climate science and projections for changing climate conditions into existing public health programs and decision-making including the State Health Improvement Plan and community health planning conducted by counties and health care systems. • Consider the public health impacts of climate change as part of state and local planning and decision-making such as infrastructure investment, land use planning and community development.
Assess	• Through data analysis and community engagement, assess disease burden resulting from changing climate conditions and make the resulting data available to state and local public health practitioners and health systems to inform planning and programs. • Identify existing public health programs that can be modified to serve as delivery mechanisms for interventions to address health outcomes of changing climate conditions.
Support	• Develop and assist in the deployment of data, tools and other resources to assist local public health practitioners in implementing interventions to address climate-related health outcomes. • Provide support to health systems to anticipate how changing climate conditions may affect their own operations and needs of their patients.
Build Capacity	• Expand the ability of New Jersey's public health practitioners to undertake interventions to address climate-related public health impacts through training, development of best practices, and information sharing. • Educate lawmakers and other decision-makers about the impacts of changing climate conditions on public health in New Jersey and about the resources needed by public health practitioners to address those impacts.

With the issuance of the Climate and Health Profile Report, the New Jersey Climate Change and Public Health Workgroup provides an important forum for engaging dialogue among key partners on advancing this framework. Opportunities and areas of focus for the Workgroup include:

Act

- ✓ *Implement specific actions that have already been identified as important to minimize public health risks from changing climate conditions.*
- ✓ *Identify specific communities and populations most vulnerable to changing climate conditions and design interventions that prioritize their needs.*

While further work is needed to better understand the disease burden that New Jersey can expect to result from changing climate conditions, there is no need to wait to act now on addressing the public health impacts of changing climate conditions.

Over the past 6-7 years, there has been a variety of recommendations on specific strategies that can be undertaken to better prepare New Jerseyans and the state's public health system to address the public health implications of climate change:

- In 2014, the New Jersey Climate Adaptation Alliance issued a report with more than 45 public policy recommendations to enhance New Jersey's ability to adapt to and be prepared for changing climate conditions (NJCAA 2014a). Twenty-five of those recommendations have either direct or indirect impacts on public health and public health programs and systems. The recommendations were prepared based on research conducted over 18 months and with stakeholder engagement including the state's public health community. Several reports provide important basis and background to the Alliance's Policy Recommendations report including sector-specific working briefs, a summary of stakeholder engagement efforts (including with the public health community) and a gap analysis report identifying initial gaps in public policy identified as a result of research and stakeholder engagement. Additionally, the Alliance pointed to a set of specific recommendations that can improve public health outcomes during climate-related events, such as:
- Establishment of a statewide list of electronic medical prescriptions and a coordinated pharmacy plan to ensure that individuals can receive critical prescription medicines if sheltered;
- Creation of an electronic and web-based registration system within the shelter system;

- Development of programs to provide proactive resident advocacy, crisis counseling and effective communication among shelter staff and residents;
- Consideration of procedures that would allow the Governor to recruit state and local employees to staff shelters during extreme weather events;
- Development of a more comprehensive plan to address stockpile needs to ensure adequate supplies of food, water, medication, fuel and other supplies are available during emergencies; and
- Expansion of mental health and substance abuse services immediately after a climate-related event, along with proactive outreach and crisis counseling services to those in shelters and the most highly impacted communities.

In addition to the research and policy recommendations issued by the Climate Adaptation Alliance, several other important reports and sets of recommendations have been issued in recent years addressing climate-related public health challenges in New Jersey. Most notably, a team of researchers from several academic institutions in the region undertook the Sandy Child & Family Health Study (S-CAFH) (Abramson 2015). Among an extensive set of findings and recommendations, the S-CAFH provided the following insights related to direct public health impacts:

- Housing damage can be a risk factor for poor health that has an effect on people's lives remarkably similar to the effect of poverty.
- Exposure to mold was associated with both clinically-diagnosed asthma and with mental health distress.
- Children living in homes that experienced minor damage were at particularly high risk for psychological and emotional issues.

As part of its stakeholder engagement effort, the New Jersey Climate Adaptation Alliance also worked in partnership with the New Jersey Environmental Justice Alliance to host a Climate Justice Roundtable on September 28, 2013. The gathering brought together thought leaders, residents of Environmental Justice communities and others to focus on the types of actions and policies that are needed to ensure that policies and actions to address climate change ensure that specific policies are designed to address the unique and significant challenges facing communities of color that are disproportionately burdened by environmental pollution. Along with outcomes of a follow-up meeting on March 29, 2014, the Climate Justice Roundtable identified a discrete section of policies and actions that are intended to enhance the preparedness of residents of Environmental Justice communities regarding impacts from climate change. (NJCAA 2014d).

Other ongoing policies clearly make a difference in improving public health and will continue to play an important role in protecting public health under changing climate conditions. For example, health-based standards in New Jersey that address air quality will continue to be critically important as changing climate conditions exacerbate health outcomes caused by air pollution including ground level ozone and particulate matter, including black carbon.

Further attention needs to be paid to the identification of populations and communities that are especially vulnerable to changing climate conditions. While the expectation is that the current public health system in New Jersey may serve as an effective delivery mechanism for interventions designed to address public health impacts of climate change, there is a clear need to determine if the current public health system can systematically address the needs of vulnerable populations and communities given current health disparities across the state. Engagement of residents that are especially vulnerable to changing climate conditions, regardless of whether it is because of their demographic, health, geographic or socioeconomic status, is an important first step to ensuring that public health programs, policies and interventions are designed to address the underlying conditions that make certain populations and communities more exposued to risks associated with and less adaptive to changing climate conditions. Populations and communities most vulnerable to changing climate conditions must be a priority of public health programs, policies and interventions designed to address climate change.

The release of this Climate and Health Profile Report provides an important juncture to review recommendations of previous work including the Climate Adaptation Alliance, the S-CAFH, the Environmental Justice Alliance and other recommendations to create a workplan of immediate actions that can and should be undertaken in New Jersey. With release of this Climate and Health Profile Report, the Working Group will conduct a roundtable to identify the most pressing and value-added actions that can and should be undertaken to address public health impacts of climate change in New Jersey early in 2018.

Plan

- ✓ *Integrate climate science and projections for changing climate conditions into existing public health programs and decision-making including the State Health Improvement Plan and community health planning conducted by counties and health care systems.*
- ✓ *Consider the public health impacts of climate change as part of state and local planning and decision-making such as infrastructure investment, land use planning, hazard mitigation planning, and community development.*

An adaptive management approach to addressing public health impacts of climate change necessitates the need to integrate the latest climate science and the anticipated public health impacts of changing climate conditions **into existing planning processes at the State and local level**. This approach allows for full integration of public health-related climate change impacts into planning processes that drive State and local decision-making including resource allocations, program development, regulatory standards and establishment of preparedness requirements for the private sector.

There is definite synergy between the next steps in this report and relevant provisions in the State Health Improvement Plan. The State Health Improvement Plan (NJDOH 2012), also known as Healthy New Jersey 2020, includes the establishment of baseline data and targets that are intended to be addressed through the provisions of the Plan. The Plan focuses on five leading health indicators that are intended to reflect the State of New Jersey's major public health concerns based on the benchmarking outlined in Healthy New Jersey 2020. Of those five health indicators, three – birth outcomes, heart disease, obesity - have direct or indirect connections to climate-related health outcomes. This synergy provides valuable opportunities to identify strategies to integrate consideration of changing climate conditions into disease prevention efforts underway and planned as part of the State Health Improvement Plan. Incorporating consideration of projected climate conditions into Healthy New Jersey 2020 can help to ensure associated policy and programs are adequately protective.

In addition to informing statewide efforts under Healthy New Jersey 2020, the content of this Climate and Health Profile Report provides a valuable reference point for integration of consistent climate science and articulation of anticipated public health impacts into a variety of other extant planning processes. Incorporating consideration of future climate conditions, anticipating the communities and populations most vulnerable to those conditions, and integrating a strong public health "voice" into these planning processes offers valuable opportunities to deliver positive health outcomes and health equity in New Jersey:

- County Health Improvement Plans which can ensure that programs and strategies reflect anticipated health and safety outcomes under changing climate conditions;
- Community Health Needs Assessments which can ensure that health systems are fully prepared to address the health needs of its communities and populations under changing climate conditions both associated with assessing vulnerability of their own operations and well as assessing the healthcare delivery needs of especially vulnerable populations and communities;

- Municipal and County Master Plans which have significant potential to result in positive health outcomes under changing climate conditions by ensuring that people, infrastructure and critical assets are not located in harm's way;
- Hazard Mitigation Plans which can ensure that systems are in place that fully consider public health and safety in the case of natural disasters given changing climate conditions. There is a need to ensure that outreach is conducted during natural disasters that provide crisis counseling and clinical services in times of distress; and
- Regional (multi-municipal) and local Resilience plans which have the opportunity to integrate consideration of health outcomes into post-disaster community planning as was done through a partnership in Galveston, Texas (Nolen 2010). There is a growing recognition that resilience planning and post-disaster recovery planning are critically important opportunities to consider the health and wellness of communities with the recognition that communities that are resilient to changing climate conditions contribute to the mental and physical health and wellness of residents.
- Ensure that all efforts to integrate consideration of health impacts from changing climate conditions includes both physical and mental health. As noted already, a recent study from the American Psychological Association found that "building resilience is essential to address the physical and mental health impacts of climate change. Many local governments within the United States and in other countries have created plans to protect and enhance infrastructure, but these plans tend to overlook the support needed to ensure thriving psychological well-being. There is an opportunity to include the resilience capacity of individuals and communities in the development of preparedness plans." (Clayton 2017).

Several state and local jurisdictions across the United States are moving towards a public health paradigm that embraces the concept of "health in all policies" (HiaP) in which collaborative efforts advance strategies that improve the health of all people by incorporating health considerations into decision-making across sectors and policy areas. A "health in all policies" approach inherently offers important opportunities to New Jersey to consider climate-related impacts to health and health equity because, by its nature, HiaP is designed to integrate health into other planning, policies and decision-making including in sectors critical to protecting the health and safety of New Jerseyans from changing climate conditions such as environmental and natural resource protection, land use, transportation and energy planning, design of the built environment and infrastructure, and community development and revitalization (Rudolph et al. 2013).

Another opportunity to consider is whether New Jersey's efforts to address climate-related public health challenges would benefit from the establishment of a collaborative, partner-driven nonprofit organization dedicated to advancing public health practice and making systematic improvements in population health. In other states such as in California, a public health institute serves as a convening entity on assessing impact of multi-sector climate change policies on health.

Several actions are needed to advance the objective of integrating climate science and consideration of public health-related climate impacts into existing planning processes, including: guidance, technical assistance and development of decision-support tools that can be used by State and local planners, documentation and education about best practices for planning integration, and demonstration of effective strategies in order to develop a "community of practitioners" statewide.

In its service role as the state university, a multidisciplinary team at Rutgers has been working to develop and deploy climate science-based decision support tools to aid coastal communities in developing resilience planning efforts. A similar collaborative approach including climate scientists, public health practitioners, planners and public health experts can provide similar opportunities to incorporate the insights synthesized in this Climate and Health Profile Report into specific and tangible provisions of existing planning mechanisms. This effort will be most impactful if done in close collaboration with those agencies and authorities that oversee execution of planning provisions. In addition, opportunities should be identified to educate New Jersey practitioners about similar efforts outside New Jersey that may be more fully developed at this time which can augment New Jersey planning provisions.

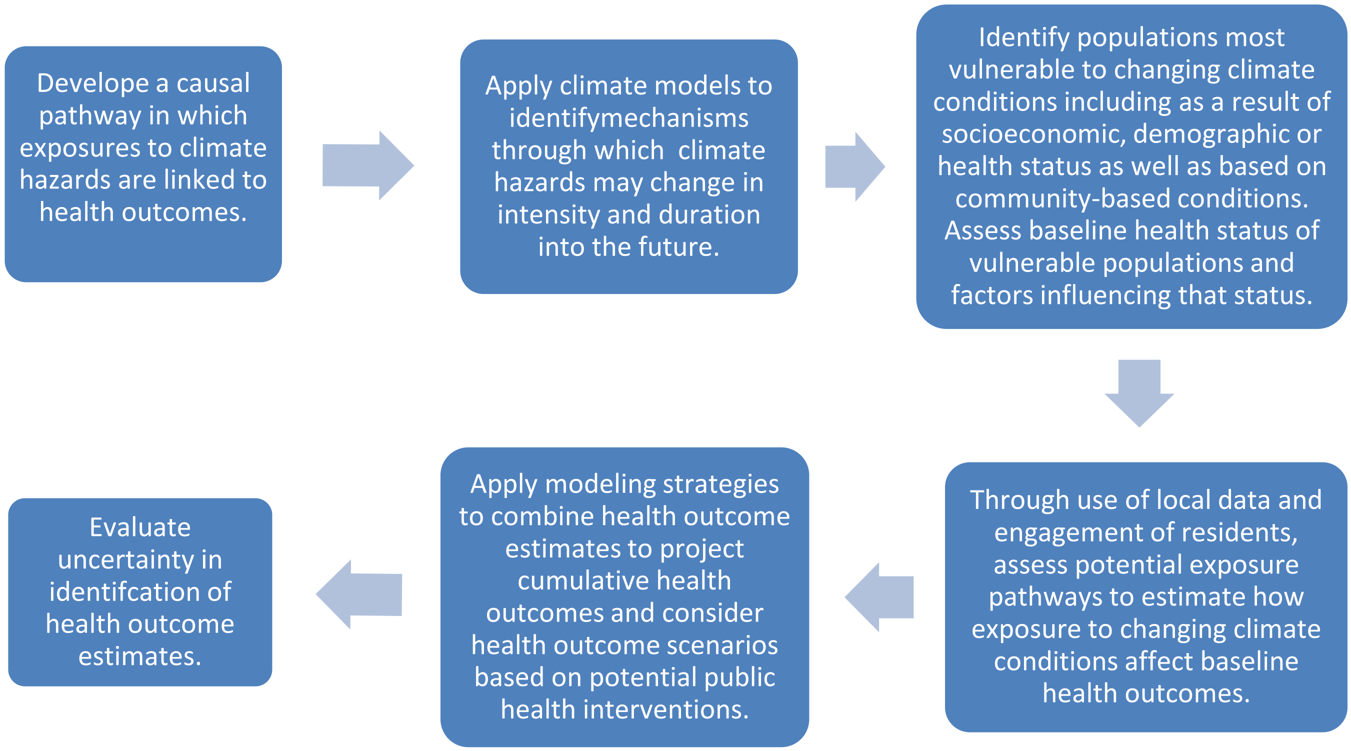
Assess

- ✓ *Through data analysis and community engagement, assess disease burden resulting from changing climate conditions and make the resulting data available to state and local public health practitioners and health systems to inform planning and programs.*
- ✓ *Identify existing public health programs that can be modified to serve as delivery mechanisms for interventions to address health outcomes of changing climate conditions.*

This Climate and Health Profile Report serves as an important initial tool to further raise awareness among public health practitioners in New Jersey about the potential impacts of a changing climate on public health. The Workgroup intends to use this report as a vehicle to engage the public health community more actively in efforts to quantify additional burdens of health outcomes associated with climate change. In doing so, the Workgroup will advance application of the CDC BRACE framework in New Jersey.

Following Step 1 of BRACE in which climate change impacts and public health vulnerabilities are forecasted resulting in a Climate and Health Profile Report, Step 2 involves a more quantitative process of estimating future burden of disease for climate-related health outcomes so that those outcomes can be ranked for priority action and public health interventions and health adaptation plans can be developed (Jess 2015). It is important to stress that a quantitative disease burden assessment is a significant undertaking and while there is value in developing more measurable causal connections between changing climate conditions and health outcomes, waiting to undertake appropriate public health interventions until a full disease burden is undertaken is not necessary. New Jerseyans are already facing the public health impacts of climate change and the severity and frequency of those impacts will only continue to increase in the coming years. Immediate action is needed in New Jersey to plan for and act to mitigate the impacts that changing climate conditions will have on public health. Research is currently being conducted on behalf of the New Jersey Climate Adaptation Alliance to assess approaches by which proactive advancement of public health actions and interventions can take place concurrent with more in-depth assessment of disease burden.

Following CDC guidance (CDC 2014), a projection of disease burden involves six components:



To the extent climate and health outcome data are available, this process of projecting disease burden can result in a quantitative assessment of anticipated health outcomes with an understanding of vulnerable populations. If local climate and/or health data are not available, data from the scientific and public health literature is used resulting in a more qualitative assessment. Nevertheless, the result of this process is the identification of anticipated health outcomes as a result of changing climate conditions that allows decision-makers to identify and prioritize public health interventions.

The Workgroup believes that undertaking the projection of disease burden will allow for a systematic and strategic identification of needed public health interventions to address climate-related health outcomes. Resources permitting, the Workgroup intends to combine a consultative process with climate scientists with a public health expert panel approach in order to identify, project and rank climate-related health outcomes as well as identify especially vulnerable populations that should be priorities for any subsequent identification of public health interventions. Additionally, the Workgroup suggests that proactively engaging affected communities, especially populations and communities most vulnerable, is a critically important element of assessing disease burden and setting priorities for public health programs and interventions.

Coincident with the assessment of anticipated disease burden as a result of changing climate conditions is the need to identify existing policies and programs that have the potential to improve health and health equity if consideration of future climate conditions were incorporated into their design. For each health impact and set of diseases identified that New Jersey can anticipate from changing climate conditions, an identification of multi-sector policies, programs and interventions needs to be identified so that appropriate modifications can be made to ensure that health outcomes from future climate conditions are addressed.

Support

- ✓ *Develop and assist in the deployment of data, tools and other resources to assist local public health practitioners in implementing interventions to address climate-related health outcomes.*
- ✓ *Provide support to health systems to anticipate how changing climate conditions may affect their own operations and needs of their patients.*

There is an immediate need to begin efforts now to support public health practitioners in efforts to undertake programs designed to reduce climate impacts on health. Examples of efforts in other states participating in the CDC Climate Ready States and Cities Initiative are available and a variety of specific efforts were discussed at the Workgroup's June 3, 2016 conference. Some efforts are designed to raise awareness about climate-related health impacts among public health practitioners, and others are intended to build and provide ready-made tools that local public health practitioners can use to reduce public health impacts of climate change. The objective of this effort is to provide the support needed by state and local public health practitioners in New Jersey for undertaking policies, programs and strategies to address climate-related public health impacts. Several specific efforts raised at the June 3 conference and discussed by the Workgroup as important initial efforts needed in New Jersey include:

- Create tailored New Jersey-specific data and tracking tools that can be used by public health practitioners. The State of Massachusetts has developed such a program, creating tailored localized data using the CDC Environmental Public Health Tracking Program (CDC 2012) and creating tailored data packages for local health departments (See: https://blog.mass.gov/publichealth/environmental-health/massachusetts-environmental-public-health-tracking-epht-climate-change/). Data regarding health outcomes of climate conditions can be tailored to New Jersey to support public health programs and raise awareness in the general population.

- Design, develop and deploy effective strategies to engage affected populations, especially residents and communities that are most vulnerable to changing climate conditions, in the process of assessing vulnerability and identifying meaningful public health programs, policies and interventions.
- Develop free and easily accessible educational materials that public health practitioners can use for education and outreach of the general public; these should be available in web-based as well as reproducible formats.
- Using existing data and analyses regarding populations in New Jersey that are vulnerable to changing climate conditions (Pflicke 2015), develop guidance and tools that can support efforts of practitioners to consider the needs of such populations when developing climate-related public health interventions.
- Deploy the practice of Health Impact Assessment (HIA) to assess health impacts of decisions associated with climate change and resilience policies and programs. HIA is a tool that can be more widely integrated into assessment processes by non- health decision makers to assess a proposed plan, project or policy that would have traditionally not considered health outcomes. HIA employs a systematic process combining scientific data, health expertise and public health input to identify and assess the potential positive and negative health effects early in a decision-making process to lead to improved health outcomes in the land use, energy, transportation, and housing sectors (NRC 2011). In New Jersey, HIA has been conducted for resiliency planning in two seminal reports. The first examined a proposed stormwater management plan for the City of Hoboken including the potential health effects of flooding and exposure to polluted stormwater; disruptions in local, emergency and business services due to flooding, changes in water and air quality; and effects on permeability and heating related to green infrastructure solutions (Carnegie 2016). The second assessed the physical and mental health outcomes associated with implementation of voluntary residential buy-out scenarios for properties repeatedly flooded and at continued risk of flooding from sea-level rise in Little Egg Harbor Township, NJ (Lowrie 2016). Policies, plans and projects to address climate change mitigation and adaptation could benefit from integration of HIA to support not only local public health practitioners, but also non-health decision makers with policies, projects or plans to address climate resiliency and greenhouse emissions reductions. An overall examination of HIA as a tool to inform resilience planning using the two New Jersey cases as examples, found that HIA not only provides an effective framework for integrating health into resilience planning but it also serves to create a structured, yet nimble, methodology to undertake extensive community engagement to inform resilience and pre-disaster planning (Mitchell 2016).

- Summarize downscaled climate science and future climate projections into guidance and communication tools that can be used by public health practitioners as part of local planning and development of interventions. Downscaling is the analytical procedure in which global climate data is assimilated to allow for making predictions at more local levels (UCAR 2016). New Jersey public health practitioners can benefit from a shared set of downscaled data that can consistently be used statewide.

In addition to the need to develop resources, data and tools to support work of state and local public health practitioners, health systems across the state can benefit from information exchanges that can identify both how changing climate conditions can increase vulnerability of health systems' own operations as well as the health of patients that use those health systems. The climate science and data are currently available that can inform planning efforts of health systems to increase the resilience of their own facilities and operations as well as to anticipate potential changes in services that may be needed as disease burdens of their patient population changes as a result of changing climate conditions.

Build capacity

- ✓ *Expand the ability of New Jersey's public health practitioners to undertake interventions to address climate-related public health impacts through training, development of best practices, and information sharing.*
- ✓ *Educate lawmakers and other decision-makers about the impacts of changing climate conditions on public health in New Jersey and about the resources needed by public health practitioners to address those impacts.*

There is a critical need to build enhanced capacity into existing public health programs and delivery systems as the climate continues to warm. The Workgroup provides an important forum for identifying needs of New Jersey's public health community to systematically target and address climate-related health outcomes. The objective of building capacity within the state's existing public health systems and programs is intended to develop a "community of practice" resulting in multiple benefits:

- Facilitating technical assistance from and collaboration among the climate science and public health communities;
- Increasing public health practitioners' access to data and decision-support tools to integrate climate considerations into public health practice;
- Creating opportunities to share effective intervention strategies to address climate-related health outcomes; and

- Engaging the public health community to come together to articulate shared needs in terms of resources, data, and training, among others.

Several areas identified by the Workgroup as having value to increasing capacity among New Jersey's public health practitioners to advance interventions to address public health challenges from changing climate conditions include:

- Using existing continuing education programs for public health practitioners (workshops, webinars, etc.) to offer trainings and educational opportunities on specific topics with a strong emphasis on public health practice. Initially, these efforts can benefit from various resources that have already been developed, some of which are mentioned throughout this report;
- Securing resources to support demonstration projects with local public health practitioners in assessing climate-related health outcomes and implementing public health interventions;
- Providing opportunities for New Jersey public health practitioners to participate in national communities of practice within the CDC Climate Ready States and Cities Initiative;
- Working with partners in other sectors, such as transportation, emergency management, and natural resource protection, where integrating consideration of changing climate conditions in planning and decision-making for sector-related objectives can create co-benefits of improving health outcomes; and
- Securing resources to create a mini-grant program to promote innovation among local public health practitioners.

In addition to increasing awareness among public health practitioners about climate-related health impacts, the Workgroup also identified the need to educate lawmakers, other elected officials, the funding community and other decision-makers about the anticipated impact that changing climate conditions will have on public health in New Jersey. These education efforts are intended to:

- Ensure that adequate resources are available to the public health community to be prepared for changing climate conditions, including to gain support for implementation of the recommendations in this Climate and Health Profile Report;
- Begin a dialogue regarding potential changes to current practices and policies that may be needed to ensure that the state's public health systems are prepared for public health impacts and changes to disease burden that are

anticipated as a result of changing climate conditions; and

- To promote strategies that integrate consideration of health into overall climate change policies affecting other sectors (e.g. transportation, energy, etc.).

Overall, there are significant opportunities to improve health and well-being among New Jerseyans through consideration of climate-related health outcomes. This Climate and Health Profile Report provides an important step forward for development of collaborative initiatives engaging climate scientists, public health practitioners, public policy decision-makers, and subject area experts.

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